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UNION OF SOUTH AFRICA

DEPARTMENT OF COMMERCE AND INDUSTRIES

THE SOUTH AFRICAN PILCHARD
(Sardinops ocellata)
AND MAASBANKER
(Trachurus trachurus)

THE CHAETOGNATHA OFF THE WEST COAST OF THE UNION OF SOUTH AFRICA.

JULY, 1954 — JUNE, 1955.

BY

A. E. F. HEYDORN, M.Sc.
(Assistant Professional Officer).

INVESTIGATIONAL REPORT No. 36.

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I. SUMMARY.

This investigational report is a further contribution to the series on the general biology and environment of the South African Pilchard, *Sardinops ocellata* (Pappe), and Maasbanker, *Trachurus trachurus* (Linné), and deals with the chaetognaths off the west coast of South Africa.

The *Chaetognatha* found in the plankton hauls done by R.S. *Africana II* in its routine research area during the period July, 1954, to June, 1955, were examined. An attempt has been made to correlate the occurrence of the various species with the hydrological conditions in the research area during the year of observation on an annual and a seasonal basis. The following are the findings of this investigation:—

1. Four genera and twelve species were found. Of these, only three species occurred in large numbers. These were: *S. friderici*, *S. minima* and *S. serratodentata.*

2. It was found that *S. friderici* is a neritic species, typical of the cool, inshore water of the research area, while *S. minima* occurred in largest numbers in the warmer, off-shore region.

3. Computations of coefficients of correlation have shown that the association of these two species with the two types of water is of a highly significant nature.

4. *S. serratodentata* is a eurythermal form and its distribution in the research area could not be related to the temperature and salinity of the water in any way.

5. The occurrence of specimens of *S. enflata*, *S. regularis*, *S. robusta* and *S. neglecta* in the research area, is of special interest as they have been recorded from the Agulhas current by previous workers, but are not normally associated with the cool Benguela current. The presence of *S. enflata* and *S. regularis* in the southern part of the research area during the latter half of July, 1954, suggests that a vagary of the Agulhas current reached, and mingled with, the Benguela current during that period.

6. An attempt was made to correlate the occurrence of *S. friderici*, *S. minima* and *S. serratodentata* with the occurrence of pilchard eggs. No such correlation could be established.

7. Although it cannot be proved at this stage, it is suggested that *Chaetognatha* can do considerable harm to the stocks of larvae of commercially important species of fish.

II. INTRODUCTION.

The *Chaetognatha* are a group of invertebrate animals which have puzzled zoologists ever since they were discovered by Martin Slabber in 1775. Burfield (1927) goes into the question of affinities and the confusion this phylum has caused, in detail. It therefore suffices to state here that various authors have attempted to assign the *Chaetognatha* to the following phyla: *Coelenterata*, *Nematoda*, *Arthropoda*, *Mollusca*, *Vertebrata*, *Enteropneusta*, *Annelida*. At the present stage of our knowledge, the *Chaetognatha* are generally regarded as a separate phylum.

Although *Chaetognatha* were found in the Benguela current during marine biological expeditions such as the *Meteor* expedition (1925–27) and the *William Scoresby* expedition (1950), a detailed study of their distribution was never possible, as the stations on these expeditions necessarily had to be spaced far apart, and could usually be covered only once during each expedition. The routine research area of the Division of Fisheries' research ship, *Africana II*, covers a part of the Benguela current which is of importance to the pilchard and maasbanker fishing industry of the Union of South Africa. In this area vertical, horizontal and oblique plankton hauls were made by R.S. *Africana II*, at 24 fixed stations, once during each month of the year of observation. The stations and plankton hauls will be dealt with in more detail later. A detailed study of the chaetognath fauna in this area over a period of one year, was therefore possible.

The purpose of the work is to find out which species of chaetognaths occur in the research area, to determine their distribution on a seasonal basis, to find out whether the various species can be used as indicators of different hydrological conditions, and whether there is any special relationship with other plankton organisms, especially pilchard eggs.

A survey of the literature has revealed that the following species have been found in South

African waters. Those species found in the present collection have been marked (A):—

Sagitta friderici Ritter–Zahony (1911) (A).
Sagitta minima Grassi (1881) (A).
Sagitta serratodentata Krohn (1853) (A).
Sagitta enflata Grassi (1881) (A).
Sagitta regularis Aida (1897) (A).
Sagitta planctonis Steinhaus (1896) (A).
Sagitta hexaptera d'Orbigny (1853) (A).
Sagitta robusta Doncaster (1902) (A).
Sagitta neglecta Aida (1897) (A).
Sagitta bipunctata Quoy and Gaimard (1827).
Sagitta bedoti Beraneck (1895).
Sagitta maxima Conant (?).
Sagitta decipiens Fowler (1905).
Sagitta lyra Krohn (1853).
Sagitta macrocephala Fowler (1905).
Pterosagitta draco Krohn (1853) (A).
Krohnitta subtilis Grassi (1881) (A).
Eukrohnia hamata Möbius (1875) (A).
Eukrohnia fowleri Johnston and Taylor (1921).

As it was not possible to obtain all original reports, this list has been compiled from the following publications: Cleve (1905), Ritter–Zahony (1909b, 1911a), Gray (1923), Thomson (1947), Fraser (1952) and a list of the species which were found during the *William Scoresby's* first survey of the Benguela current. This list was kindly put at my disposal by Dr. P. M. David, of the National Institute of Oceanography, Surrey, England.

From the list above it can be seen that four genera and twelve species were found in the research area during the year of observation. Of these, *S. friderici* and *S. minima* were caught in very large numbers and show a definite preference for inshore and off-shore water, respectively.

Each species will be dealt with and described in detail later. The descriptions are based on those of Ritter–Zahony (1911a), Burfield and Harvey (1926), Tokioka (1939, 1940a, 1940b, 1954a, 1954b), Thomson (1947), and Fraser (1952), but are modified to represent the species in the present collection. The differences, if any, are however very small. Any other references used, will be mentioned in the text.

A few tattered juveniles of probably *S. lyra* and *S. macrocephala* were found, but they could not be identified with certainty.

The identification of *Chaetognatha* is made difficult by the fact that some species resemble each other closely. Examples are: *S. gazellae* and *S. lyra; S. friderici* and *S. setosa;* and *S. planctonis*, *S. zetesios* and *S. marri*. This has led to a lot of misunderstanding in the literature and has made many records unreliable.

Juvenile forms also resemble each other to a very great extent. The tail segment taken as a percentage of the total body length, is usually larger in juveniles than in adults. Characteristics such as ovaries and seminal vesicles are undeveloped and the small size makes the counting of the head armature extremely difficult. Juveniles were therefore disregarded, unless their identity was very clear.

A generic and specific key, covering all the South African species, may be found in Thomson (1947).

III. THE RESEARCH AREA.

The research area consisted of a network of 24 stations, worked once a month by R.S. *Africana II*, and was referred to by de Jager (1954) as the "routine offshore area". Except for 4 stations situated between Saldanha Bay and Table Bay, this network of stations is bounded by Saldanha Bay in the south and Lambert's Bay in the north, and extends seawards for some 80 miles at the north and 40 miles at the south. The total area is approximately 4,000 square miles. (See Plate I.)

Besides these, a special off-shore station (Y) was introduced for closing-net hauls which will be described on page 6.

IV. MATERIAL AND METHODS.

A. The Samples.

The samples were taken by R.S. *Africana II* during the course of the Pilchard Research Programme of the Division of Fisheries. As de Jager (1954) states, all the plankton-nets used in this work were of the standard types as used by R.R.S. *Discovery II*. A full description of these, together with the methods of their operation, may be found in *Discovery* Reports [Kemp, Hardy and Makintosh (1929)]. Chaetognaths were taken in the following hauls, which were all made during daytime:—

(*a*) A vertical N70V plankton net haul from 100 metres (or 5 metres from the bottom if the

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depth was less than 100 metres) to the surface was made at each station except station P, where the water is too shallow. All the *Chaetognatha* were extracted from the vertical hauls from 23 stations for 12 successive months. This period was from July, 1954, to June, 1955. Thus the *Chaetognatha* found in 276 N70V hauls were examined. This makes possible a quantitative and qualitative comparison of the *Chaetognatha* in the upper layer of the research area, mainly between 100 metres and the surface of the sea.

(*b*) A horizontal N100H plankton tow-net haul at 0–5 metres made at each station including station P. Each of these horizontal hauls was made directly after the vertical haul. The towing time of the N100H net was exactly 10 minutes. The *Chaetognatha* were extracted from these hauls during five successive months when the samples were available. This period was from January to May, 1955. Thus 120 N100H hauls were examined and a comparison of those forms which occur at the surface during daylight became possible.

(*c*) A survey of the *Chaetognatha* in a certain area is not complete without a knowledge of the deeper-living forms as well. Unfortunately it was not possible to use a closing net at each station for practical reasons. A closing-net was therefore used at only one station (Y) once a month. The *Chaetognatha* found in these hauls were examined for the six months April to September, 1955. The net used was a closing N70V plankton-net, and hauls from the following depths were examined:—

600–400 metres.

400–200 metres.

200–0 metres.

B. The Extraction of *Chaetognatha* from the Samples and Methods used for their Identification.

Chaetognaths are soft-bodied animals and special care has to be taken in their handling and preservation. It was found that handling them with forceps or dissecting needles often caused considerable damage, making later identification more difficult. A wide-mouthed dropper was found to be far more satisfactory. The delicate anterior fins are especially prone to damage (see Plate 2). To lessen the amount of damage done during handling, the specimens were, whenever possible, identified as soon as they were taken out of the original plankton samples. After identification they were kept in separate specimen tubes in 5 per cent formalin neutralised with borax, which proved satisfactory as a preservative.

Various methods of identification were tried, including the counting of seizing jaws and teeth (see Plate 2). The most successful method was to place a specimen on a glass slide, add a drop or two of water to the head region and cover with a cover slip. Slight pressure with a dissecting needle on the cover slip helped to spread the seizing jaws. Counting of the armature was then relatively simple under the lower magnification of a research microscope. It usually sufficed to view the animal from the dorsal side only. Once the various species were known, they could usually be identified by ordinary inspection under a dissecting microscope.

The only external feature which requires staining is the *corona ciliata*. Unfortunately this organ is frequently damaged in the plankton nets or by handling, and is useful only as a confirmatory characteristic. Fowler's (1905) method of immersing the animal for about one minute in a 1 per cent solution of methylene blue gives the best results. As Thomson (1947) points out, staining is also necessary to make the gonads of opaque species more visible. In transparent and moderately opaque species, the ovaries, testes, spermatocytes and spermatozoa can be distinguished easily without staining. In those species with thinner muscle walls, immersion in 5 per cent methylene blue for five minutes brings the gonads into sharp relief. Thomson recommends the use of borax-carmine followed by methyl blue for the most strongly muscled species, but this was never found necessary.

V. NOTES ON THE HYDROGRAPHY OF THE RESEARCH AREA.

The research area lies in the Benguela current, which may be described as a mass of cool water flowing northwards along the west coast of South Africa, and which is most conspicuous between Cape Point and 17°S. to 18°S. (Sverdrup, Johnson and Fleming, 1946). The two main components of this current are of different origin, giving it a

mixed sub-tropical and sub-antarctic nature. These two components are—

(*a*) a mass of relatively warm water flowing northwards, which is the most eastern part of the South Atlantic Gyral;

(*b*) cold upwelling water which contains water of Antarctic origin and which is rich in nutrients. This water is brought to the South African west coast by the Antarctic Intermediate current, the upper part of which upwells and flows over the continental shelf. The upwelling is enhanced by a westerly component which takes water away from the coastal regions, and which is especially conspicuous during summer when strong southerly winds are prevalent. For this reason upwelling is usually much stronger during summer than during winter, with the result that the temperature and salinity of the water near the coast are lowest during the summer months.

In agreement with the dynamics of currents in the southern hemisphere, denser water of lower temperature and salinity is found on the right hand side of the current, i.e. close inshore, while warmer water of higher salinity is found farther off shore.

Whether a component of the warm Agulhas current can round the Cape of Good Hope under certain conditions and mingle with the Benguela current, is a question which has caused a lot of controversy. If this is possible, the Benguela current in the vicinity of Cape Town should at least contain elements of warm, sub-tropical, Indian Ocean water. In the light of this, the Indian Ocean forms found in the southern part of the research area are of the greatest interest. This will be dealt with in detail later.

Before attempting to correlate the occurrence of various species of *Chaetognatha* with the temperature and salinity of the water, it is necessary to determine whether there is a relationship between the temperatures and salinities themselves. The coefficient of correlation was computed, giving the extremely high value of r=0·984. For details see section VII.

VI. THE OCCURRENCE AND DISTRIBUTION OF THE VARIOUS SPECIES FOUND IN THE RESEARCH AREA.

1. *Sagitta friderici* Ritter-Zahony (1911).

Sagitta friderici Ritter-Zahony (1911a); Faure M-L (1952); Furnestin M-L (1953c); Thomson (1947); Fraser (1952).

A. Geographical Distribution.

Surprisingly little could be found in the literature about the distribution of *S. friderici*. It has been recorded as a neritic species and has been found in the following regions:—

Canary Islands—Ritter-Zahony (1901).
Morocco—Faure (1948, 1949, 1950).
Benguela Current—*William Scoresby* Expedition (1950); Fraser (1952).

B. Description.

This is a relatively rigid species with *vesiculae seminales* close to both posterior and tail fins. It has been confused with *S. bipunctata* which is an oceanic species, and with *S. setosa* which has not yet been recorded from the southern hemisphere.

Characters:—

Anterior fins—relatively small; start close behind ventral ganglion, completely rayed, becoming broader to the posterior and completely separated from the posterior fins. *Posterior fins*—slightly larger and broader than the anterior fins, completely rayed and situated slightly more on tail than on trunk. *Tail*—18 per cent to 24 per cent. *Anterior teeth*—small, up to eight. *Posterior teeth*—small, up to 20. *Hooks*—up to nine. *Corona ciliata*—approximately two times the length of the head, starting just behind or in front of the eyes. *Collarette*—small. *Gut diverticulae*—absent. *Ovaries*—relatively short but may reach posterior end of anterior fins. *Vesicula seminales*—relatively long with prominent anterior thickening, touching both posterior and tail fins. *Length*—up to 18 mm.

C. The Distribution of *S. friderici* in the Research Area.

(i) Horizontal Distribution on an Annual Basis.

S. friderici is known as a neritic species and one would therefore expect to find it in largest numbers at the stations close inshore. This is well illustrated by the specimens found in the N70V hauls taken in the research area during the 12 months of observation (see Table I, Graph I and Plate I). Stations U, V, W, X and S are not taken into consideration here, as they are not situated on lines of common latitude. Graph I was compiled from the total number of specimens caught at each of 19 stations during the year of observation, i.e. from 228 N70V hauls. It will be noted that where the stations are situated on the same latitude, i.e. from R to T, from Q to A, from N to B and from M to C, *S. friderici* occurs in largest numbers at the inshore stations R, Q, N and M.

The large number of specimens taken at stations M and N are especially noteworthy, as the depth of these two stations is only 80 metres, so that the net could only fish from a depth of 75 metres.

The question now arises why this species should have such a preference for the inshore water. It is a well known fact that the neritic province is vastly different from the oceanic province in character (Sverdrup, 1946), and it is not surprising that certain species should occur here in greatest density. The factors which seem to influence the distribution of *S. friderici* will be dealt with as follows:—

(*a*) depth of the water,

(*b*) temperature and salinity,

(*c*) the density of other plankton.

(*a*) *The Depth of the Water.*—The depth of each station is indicated on Graph I and Plate I. It is apparent that—

1. larger numbers were found farther off shore at the northerly than at the southerly stations;
2. large numbers were never found in water with a depth of more than 200 metres;
3. the greatest drop in occurrence was found between the stations where the depth of the water becomes greater than 200 metres, i.e. between stations R and H, Q and I, O and J and K and D.

In the northern part of the research area, the continental shelf does not slope down as steeply as in the southern part. Thus the depth of the water at station K in the north, is not much greater than that of station R in the south, although the former is more than four times the distance from the shore than the latter. Correspondingly larger numbers occur farther off shore in the northern row of stations than in the southern row.

The question thus arises whether it is the shallowness or the associated hydrological and other characteristics which make this inshore water so suitable for *S. friderici.*

(*b*) *Temperature and Salinity.*—*S. friderici* occurred in sufficiently large numbers to make correlation with hydrological conditions possible. On Graph II the total number of this species caught at each of 23 stations during the 12 months of observation are plotted against the annual average temperature and salinity values at each station during the same period. The temperature and salinity values are the integral means of the 0–50 metres layer. The following points are of interest—

1. maximum numbers of *S. friderici* always occur when the average temperatures and salinities are lowest. (See stations U, R, Q, N and M);
2. the temperature and salinity curves follow each other closely, so that it is not possible to determine whether it is temperature or salinity which is important;
3. the drop in occurrence between stations R and H, Q and I, O and J, and K and D is accompanied by sharp rises in temperature and salinity.

It therefore becomes clear, that as the water gets deeper farther off shore, the temperature and salinity of the 0–50 metres layer increase, and this is accompanied by a marked decrease in the occurrence of *S. friderici* in the 0–100 metres layer.

(*c*) *The Density of other Plankton.*—*Chaetognatha* are predatory animals, living mainly on copepods such as *Calanus*, *Centropages* and *Oithona* which were frequently found in the gut of *S. friderici.* One would therefore expect to find this species where the concentration of other zooplankton is greatest. The settled volume values of the edible plankton of the N70V hauls (de Jager, 1954), are not an entirely true reflection of the plankton abundance, but are indicative of the relative abundance at each station, both on an annual and a seasonal basis. On Graph II the average settled volumes for each station during the 12 months of observation are also plotted. The peaks of the settled volume curves and minimum temperature and salinity values, agree with those of maximum abundance of *S. friderici* at stations R, Q and M. The graph also shows that the density of zooplankton in general is greatest at the inshore stations and decreases as one moves farther off shore.

The indications therefore are that one can expect to find *S. friderici* in largest numbers in cool, inshore water, not deeper than 200 metres, with a temperature and salinity of less than 13°C and 35‰, respectively, and in which other zooplankton is relatively abundant. It is not suggested that these variables are independent of each other but together they represent a suitable environment for the occurrence of this species.

(ii) Horizontal Distribution on a Seasonal Basis.

Results of the investigation of the distribution of *S. friderici* on an annual basis give an indication of a relationship between the occurrence of this

species and certain physical, chemical and biological conditions. The investigation of the distribution on a seasonal basis shows this relationship more clearly. The salinity of the water has, however, been omitted as the annual temperature and salinity curves follow each other so closely.

Table III gives the seasonal averages of occurrence, mean temperature (integral means of 0–50 metres layer) and settled volumes of the N70V hauls, for each of 18 stations.

The seasonal occurrence as given numerically by Table III, is shown graphically by Graph III which has been constructed in the same way as Graph I.

The grand average of Table III gives the average occurrence and mean temperatures and settled volumes for the 18 stations (i.e. the whole area covered by these stations) for each of the four seasons. It will be noticed that the occurrence of *S. friderici* is greatest in autumn and summer and much smaller in spring and winter. Correspondingly, the mean temperatures are lowest in autumn and summer, although only slightly higher in spring and winter. That the mean temperatures do not show great differences when compared with the average seasonal occurrence is understandable, since Graph II and Table III show that *S. friderici* never occurs in large numbers when the temperature of the water is higher than 13°C. The considerably higher temperatures of the off-shore stations used in the computation of the grand average would, therefore, tend to blur the effect that the temperature has on the distribution of this species.

Also the settled volume values are highest during autumn and summer and lowest during winter.

The curves of Graph III illustrating the seasonal distribution, correspond well with the curves of Graph I which illustrate the annual distribution. The following points are of interest:—

(*a*) Also on a seasonal basis it is clear that *S. friderici* occurs in increasingly larger numbers farther off shore as one moves from south to north over the research area.

(*b*) *S. friderici* does not occur in large numbers when the average temperature is higher than 13°C. At the stations with a depth of less than 200 metres, the average seasonal temperature is never higher than 13·00°C, except at station K in winter (13·41°C) and station R in winter (13·04°C). In both these cases, the occurrence of *S. friderici* is small.

(*c*) The species never occurs in large numbers where the average settled volume figure is less than 10·0 c.c. and usually this figure is considerably higher.

The only stations where conditions permit the occurrence of *S. friderici* in large numbers during winter according to the three factors mentioned above, are stations O and Q. This is reflected in the relatively large occurrence illustrated by the winter curves of Graph III and the table below:—

Station.	Number Captured.	Depth (metres).	Temp. °C.	Settled Volumes (c.c.).
O.....	264	160	12·85	10·3
Q.....	400	110	12·89	10·7

The investigation on a seasonal basis therefore also shows that factors which play a part in determining the distribution of *S. friderici*, are the depth of the water, its temperature and the density of other plankton.

In section VII, the occurrence of this species will be correlated with water temperature using statistical methods.

(iii) Vertical Distribution.

As has already been pointed out, little data are available on the vertical distribution of *Chaetognatha* in the research area, as closing-nets take too much time to be used extensively during the routine trips of R.S. *Africana II*. However, the closing-

net hauls taken at station Y were examined over a period of six months. The numbers of *S. friderici* found in the various hauls during this period, are shown in the table below:—

Depth (metres).	April.	May.	June.	July.	August.	September.	Total.
600–400.....	—	—	—	—	1	—	1
400–200.....	1	—	—	—	—	—	1
200–0.....	—	—	8	1	2	1	12

This shows that *S. friderici* can occur at depths greater than 200 metres. Reference to Table II shows that this species can and does occur in very large numbers at the surface during day-time, especially close inshore.

The question now arises whether *S. friderici* does not occur in large numbers at depths greater than 200 metres farther off shore, especially since the deeper off-shore water has lower temperature and salinity values corresponding to those of the shallower inshore water. Although no definite answer can be given with the data available, this is regarded as most unlikely. It is a well known fact that the neritic zone is the most productive zone of the sea, as minerals and plant nutrients are more readily available and as light penetrates most of the water in this zone. Conditions are therefore suitable for the development of a much denser phyto- and zooplankton population than could exist in the deeper off-shore water. It has already been shown that one of the factors which appear to influence the distribution of *S. friderici* is the density of other plankton. Light and pressure may also influence the occurrence of the species.

On the other hand, it is not surprising to find a few neritic forms in the deeper water layers off-shore, if one takes into account the strong convection currents which develop between the dense water upwelling and being transported off snore, and the warm off-shore surface water. As Currie (1953) points out, this together with the influence of the wind, results not only in horizontal eddy formation, but also in strong vertical convection currents, which can carry plankton with them and, for example, carry specimens of an inshore species off shore. One must, however, be careful to distinguish between few specimens found outside their natural habitat and large scale occurrence as of *S. friderici* in the inshore water.

2. *Sagitta minima* Grassi (1881).

Sagitta minima Grassi (1881); Aida (1897); Doncaster (1902); Krumbach (1903); Michael (1909, 1919); Ritter–Zahony (1910a, 1911a, 1911c); Shipley (1910); Oye (1918); Johnston and Taylor (1919); Gray (1923); Bollman (1934); Kuhl (1938); Tokioka (1939, 1940b, 1954a); Thomson (1947); Furnestin (1953b, 1953c); Ghirardelli (1950).

A. Geographical Distribution.

Tyrrhenian Sea (Grassi, Doncaster, Krumbach). Atlantic Ocean between 9°S. and 21°N. (Gauss Expedition). Indian Ocean near Port Natal (Gauss Expedition). South Atlantic Ocean west of South African coast between 35°S. and 25°S. North and south of this region the density decreases rapidly (*Meteor* Expedition). Indo-Pacific Ocean (Tokioka 1952). South Pacific Ocean in S.E. Australian waters (Thomson 1947).

B. Description.

Small, transparent species. Fins separate, very narrow and rounded, *Corona ciliata* usually damaged.

Characters:—

Tail—16–20 per cent. *Anterior fins*—completely rayless and start ½–1 ganglion lengths behind ventral ganglion. *Posterior fins*—larger than anterior fins, more on trunk than tail, with few rays which are almost at right angles to body. *Hooks*—7–8, only slightly curved, except for point which bends sharply inwards. *Anterior teeth*—4–5, flat with broad basis and sharp point. *Posterior teeth*—up to 14. *Corona ciliata*—long, broad, oval, starting at neck, therefore lies only on trunk and is of about 1½ head lengths, seldom visible as it is usually severely damaged. *Collarette*—absent. *Gut diverticulae*—present. *Ovaries*—very short, club shaped, with few large ova when mature. *Vesiculae seminales*—long, thin, becoming broader from back to front, touching tail fin and separated from posterior fin by about once their own length. *Length*—up to 10 mm.

C. The Distribution of *S. minima* in the Research Area.

Vertical Distribution.—According to Thiel (1938), *S. minima* occurs mainly in the depth range from 200–100 metres, off the west coast of South Africa. The table below shows the occurrence at various depths as shown by the closing-net hauls of R.S. *Africana II*:—

Depth (metres).	April.	May.	June.	July.	August.	September.
600–400	—	—	—	—	—	—
400–200	—	—	—	—	—	—
200–0	—	—	5	—	13	91

S. minima was found in no haul from a depth greater than 200 metres, nor in any N100H hauls. That this species does, however, occur in large numbers in the 100–0 metres layer during day-time is shown clearly by the N70V hauls. See Table IV.

(i) Horizontal Distribution on an Annual Basis.

(*a*) *The Depth of the Water.*—Graph V is arranged in the same way as Graph I. The total number of *S. minima* caught at each station during the year of observation, are plotted. As so few specimens were caught at stations M and N, the smaller depth of these stations may be disregarded. It is obvious that this is not an inshore species. As one moves off shore along each row of stations, the numbers of specimens increase steadily. Although there is a drop in occurrence from stations G to T and F to A, it is doubtful whether this is due to the depth of the water exceeding a certain limit, and further investigation is necessary to find out whether there is a relationship between the occurrence of this species, and other factors such as temperature and salinity.

(*b*) *Temperature and Salinity.*—On Graph VI the occurrence is plotted against temperature and salinity curves. A relationship between occurrence and temperature and salinity is indicated. In contrast to *S. friderici*, *S. minima* occurs in largest numbers in the warmer off-shore water. Minimum numbers were found at stations R, Q, N and M, the inshore stations where the temperatures and salinities were at their lowest, and where maximum numbers of *S. friderici* were found. Judging from this graph, it seems unlikely that *S. minima* would be found in significant numbers in water with a temperature and salinity of less than 10·0°C and 34·7‰, respectively. This agrees with the observations of Thiel (1938), according to whom the lowest possible barrier of distribution of this species in the South Atlantic is the 10°C-isotherm. The barriers of the main distribution are formed by the 15°C and 20°C isotherms. It therefore seems likely that *S. minima* is not found close inshore in the research area, because the temperature and salinity of the inshore water are too low. In the off-shore part of the research area, conditions are favourable for the existence of this species, although it could tolerate considerably higher temperature and salinity conditions than are prevalent here. Bumpus and Lowe-Pierce (1955), state that *S. minima* from off the coast of North Carolina was usually associated with water of which the salinity was close to 36‰.

Graph VII was constructed to clarify the relationship between the occurrence of *S. minima* and the temperature and salinity of the water. The average temperature and salinity of the 0–50 metres layer at each station during the year of observation were plotted against each other (see Tables A and B). The station is indicated at each plotted point, as well as the total number of *S. minima* captured at each station during the year of observation. The Table below was drawn up from Graph VII:—

Temperature Range, °C.	Stations.	Number of Stations.	Total Number of Specimens.	Average Number of Specimens per Station.
10·00–10·99	M, N	2	12	6
11·00–11·99	Q, L	2	52	26
12·00–12·99	U, X, R, O, K	5	316	63
13·00–13·99	V, I, J	3	186	62
14·00–14·99	H, G, F, E, D	5	602	120
15·00–15·99	W, T, A, B, C	5	499	100

The temperature range of the research area was divided into intervals of 1·0°C, and the stations were arranged according to the interval into which their average temperature falls. The total number of specimens caught at the stations which fall into each temperature interval was then divided by the number of stations in the same temperature interval. In this way comparative figures of average numbers of specimens per station were obtained for each temperature interval. An increase in numbers of specimens as the temperature increases is apparent, and a glance at the location of the stations shows that this increase is from inshore to off shore.

To determine the degree of correlation between water temperature and occurrence of *S. minima*, the coefficient of correlation was computed and found to be highly significant, even on a 1 per cent level (r=0·751). Details can be seen in section VII (page 22).

(*c*) *The Density of other Plankton.*—No food was ever observed in the gut of the specimens of the present collection.

Comparison of the curve in Graph VI of the occurrence of *S. minima* with the " settled volume curve " in Graph II indicates no correlation. No detailed work has yet been published on the distribution of the various species of copepods in the research area, so that more research work is necessary before an opinion can be given on the relationship between the distribution of *S. minima* and other zooplankton.

(ii) Horizontal Distribution on a Seasonal Basis.

Table V shows the mean occurrence on a seasonal basis. The mean temperatures are the same as in Table III. Mean settled volumes have been left out as the investigation on an annual basis shows no sign of a correlation with the occurrence of *S. minima*. The seasonal occurrence is shown in Graph VIII. The grand average of Table V shows that the occurrence is greatest in winter and spring, lower in summer and very low in autumn. From Table V and Graph VIII it can be seen that *S. minima* comes closest inshore during winter, probably because the temperature of the inshore water is higher during this season. Only very few specimens were caught when the average seasonal temperatures were less than 13°C. The fact that very small numbers were caught during autumn cannot, however, be due to low temperatures alone, as only a few specimens occurred at stations H, G, T, F, A, J, E, B, D and C during this season, although the temperatures were well above 13°C. The drop in occurrence between stations F and A during spring, summer and winter, and between G and T during summer, cannot be explained by temperature differences either, as temperatures such as 15·01°C, 15·40°C and 16·07°C are favourable for this species (see the temperatures at station A during the various seasons in Table V).

Thus it may only be said that while the temperature and salinity of the inshore water are too low for *S. minima*, conditions in the off-shore part of the research area are favourable for its existence. Within the research area of R.S. *Africana II*, the occurrence of this species in large numbers may be regarded as being indicative of warm, off-shore water.

3. *Sagitta serratodentata* Krohn (1853).

Sagitta serratodentata Hertwig (1880); Krumbach (1903); Fowler (1905); Ritter–Zahony (1908, 1909b, 1910a, 1911b, 1911c); Michael (1909, 1911, 1919); Shipley (1910); Jameson (1914); Bigelow (1915,1922, 1926); Huntsman (1919); Johnston and Taylor (1919, 1921); Gray (1923); Burfield and Harvey (1926); Burfield (1930); Russel (1935a, 1935b, 1939); Kuhl (1938); Tokioka (1940a, 1940b, 1954a, 1954b); Ghirardelli (1947, 1950); Thomson (1947); Furnestin (1953a); Fraser (1952).

Sagitta serrulata Cleve (1905).

A. Geographical Distribution.

S. serratodentata is a cosmopolitan species which has been found in all the oceans of the world. Thiel's (1938) report on the results of the *Meteor* Expedition shows that it is a eurythermal form. It cannot, however, live in water below 5°C, while fewer specimens are found in water with a surface temperature of more than 25°C. Thus it may be expected to find this species in the Atlantic Ocean between latitudes 60°N.–50°S. Jameson (1914) reports that *S. serratodentata* of the Scottish National Antarctic Expedition were found in water with temperatures ranging from 18·3°–27·5°C, and that no specimens were taken south of 40°S. Other expeditions have found it as far south as the Magellan Straits and the Falkland Islands.

B. Description.

S. serratodentata is a very rigid and slender species, usually opaque when mature. The *vesiculae seminales* stand out as horn-shaped structures and are evident in quite small individuals, making

them one of the best characters for quick identification.

Characters:—

Anterior fins—begin just behind the ventral ganglion and extend close to posterior fins. Incompletely rayed at the front and inner edges. *Posterior fins*—extend as far back as the *vesiculae seminales*, and are completely rayed except for narrow inner zone at anterior end. *Tail*—22–30 per cent. *Anterior teeth*—7–9. *Posterior teeth*—12–19. *Seizing jaws*—6–10. The serrations on the hooks can be seen only with the stronger magnifications of a microscope, as they may be much reduced, sometimes to minute knobs. *Vesiculae seminales*—very prominent, touching both tail and posterior fins, although nearer to posterior fins. *Ovaries*—very long, often extending forwards beyond ventral ganglion. *Collarette*—small in fully mature specimens. *Corona ciliata*—long and narrow, beginning between the eyes—usually badly damaged. *Gut diverticulae*—absent. Length—up to 17 mm.

This species can be divided into three sub-species. Two of these were distinguished by Tokioka (1939), as the *pacifica* and *atlantica* forms. The third form, *tasmanica*, was distinguished by Thomson (1947), whose tables show the formulae of the three sub-species. Although the armature counts overlap considerably, certain differences are apparent. *S.s. tasmanica* attains a much greater length than the other sub-species. Its formulae overlap to a much greater degree with *S.s. atlantica*, while *S.s. atlantica* has fewer hind teeth than *S.s. pacifica*. Further, there is a notable difference in the shape of the mature *vesiculae seminales* of the three sub-species.

Identification into sub-species was only found possible with mature, well-preserved specimens, all of which proved to be *S.s. tasmanica*, although there are slight differences. These are: maximum length of mature specimens is 17 mm. (Thomson, 20 mm.); minimum number of posterior teeth, 12 (Thomson, 13); maximum number of seizing jaws, 10 (Thomson, 9). These differences are, however, small and as all the other characters agree, especially the shape of the mature *vesiculae seminales*, the mature specimens of the present collection are regarded as *S.s. tasmanica* Thomson. It is very unlikely that the younger specimens in the research area belong to another sub-species.

Unfortunately no detailed information on the geographical distribution of the three sub-species could be obtained.

C. The Distribution of *S. serratodentata* in the Research Area.

Vertical Distribution.—S. serratodentata is a species which occurs mainly in the 100–0 metres layer. It also occurs at the surface as it has been found in the N100H net (see Table VI). Of the 595 specimens taken during the year of observation, 35 were found in the N100H net and 560 in the N70V net hauls. The table below shows the numbers taken with the closing-net at various depths:—

Depth (metres).	April.	May.	June.	July.	August.	September.
600–400	—	—	—	—	—	—
400–200	—	—	—	—	—	2
200–0	2	—	4	—	1	27

During the *Meteor* Expedition, closing-nets were used extensively. Thiel (1938) describes the vertical distribution of *S. serratodentata* as follows: Greatest density in 50–0 metres. At 100–50 metres, density $\frac{1}{3}$ of that at 50–0 metres. At 400 metres the density is 1/33 of that of 50–0 metres, while it is very rarely found in depths down to 1,000 metres.

(i) Horizontal Distribution on an Annual Basis.

(*a*) *The Depth of the Water.*—Graph IX is arranged in the same way as Graphs I and V. Again it is not necessary to allow for the smaller depths of stations M and N. The graph indicates no relationship between occurrence and the depth of the water. There is also no indication as to whether this is an off-shore or an inshore species.

S. serratodentata occurred in very much smaller numbers than *S. friderici* or *S. minima* in the research area during the year of observation. This is reflected in the graphs and makes the determination of optimum conditions more difficult.

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(*b*) *The Temperature and Salinity of the Water.*—A survey of the literature has shown that *S. serratodentata* can tolerate a wide range of temperatures. One would not, therefore, expect a definite relationship between the occurrence of this species and the temperature of the water in the research area, where the range is approximately 10°–17°C. The same applies to salinity. On Graph X, the average occurrence per station is plotted against the average temperatures and salinities. No correlation is indicated. The only peak in occurrence is at station L. From Table VI it can be seen that this peak is due to the 180 specimens caught at this station during March, 1955, where the mean temperature and salinity of the 0–50 metres layer were 11·57°C and 34·77‰, respectively.

(*c*) *The Density of other Plankton.*—Comparison of the occurrence curve on Graph X and the settled volume curve on Graph II gives no indication of a relationship between the occurrence of *S. serratodentata* and the density of other plankton. No food was seen in the gut of any of the specimens.

(ii) Horizontal Distribution on a Seasonal Basis.

Table VII and Graph XI show the mean occurrence of *S. serratodentata* on a seasonal basis. According to Table VII by far the largest number occurred during autumn. The high figure for this season is largely due to the relatively large numbers of specimens captured at stations L, D and C during March, 1955. It is unlikely that the depth would influence the occurrence of this species to a large extent, as that of station L is only 130 metres while those of stations D and C are 250 and 360 metres, respectively. It has already been pointed out that the temperatures within the temperature range of the water of the research area during the year of observation, are unlikely to influence the distribution of this species.

During March, 1955, the average temperatures of the 0–50 metres layer at stations L, D and O, were 11·57°C, 13·71°C and 14·31°C, respectively, which give no further indication as to what role the water temperatures play in the distribution of this species. The salinity follows the same pattern as the temperature, and no relationship between the density of other plankton and the occurrence of *S. serratodentata* could be traced. Thus, although this species occurred in largest numbers during autumn of the year of observation, it cannot be concluded that conditions during this season were most favourable for its occurrence. More research over a longer period and in a larger research area is necessary to work out the seasonal abundance of this species satisfactorily.

4. *Sagitta enflata* Grassi (1881).

S. enflata Grassi (1881); Cleve (1905); Ritter–Zahony (1909a, 1909b, 1910a, 1911a, 1911b, 1911c); Michael (1909, 1911, 1913, 1919); Shipley (1910); Jameson (1914); Germain and Joubin (1916); Bigelow (1917, 1926); Oye (1918); Johnston and Taylor (1919); Huntsman (1919); Gray (1923); Burfield and Harvey (1926); Burfield (1930); Germain (1930); Cowles (1930); John (1933, 1937); Bollman (1934); Kuhl (1938); Tokioka (1939, 1940a, 1940b, 1954a, 1954b); Delsman (1939); Thomson (1947); Ghirardelli (1947, 1950); Furnestin (1953b, 1953c);

Spadella enflata Grassi (1883);

Sagitta flaccida Doncaster (1903);

Sagitta gardineri Doncaster (1903); John (1933);

Sagitta australis Johnston (1909); Johnston and Taylor (1919).

A. Geographical Distribution.

S. enflata is a typical tropical and sub-tropical form which has been found in the warmer parts of most oceans. Ritter–Zahony (1911a) describes the limits of its distribution in the Atlantic Ocean as 40°N. and 40°S., although warm currents such as the Florida current can carry it beyond these limits. During the *Meteor* Expedition (1925–27) it was found mainly in the area of the North Equatorial current, with a rapid decrease in occurrence to the north and the south. A few specimens which were taken off the Cape of Good Hope by this expedition, were ascribed to an influx of water of the warm Agulhas current. It was found that the occurrence off the west coast of Africa, did not extend beyond the 20°C isotherm for the warmest month, while the 15°C isotherm for the warmest month was regarded as the extreme lower limit of distribution. Thomson (1947) states that this species has been found in the following waters: eastern Australia, western Australia, California, China, Japan, Philippines, East Indies, Malaya and Pacific Islands, North Indian Ocean and Red Sea, South Africa and Southern Indian Ocean, and the Atlantic. Furnestin (1955) described its distribution in the Mediterranean.

B. Description.

S. enflata is a transparent, tumid species, with short anterior fins. The shape of the testes, which are situated in the posterior part of the tail, is a good character for quick identification.

Characters:—

Anterior fins—narrow, with small, rayless inner zone, starting considerably behind ventral ganglion. *Posterior fins*—rounded, slightly larger than anterior fins, also with narrow, rayless inner zone. Situated approximately $\frac{2}{3}$ on trunk. *Seizing jaws*—up to 10. *Tail*—14–21 per cent. *Anterior teeth*—up to 10. *Posterior teeth*—up to 18. *Corona ciliata*—short, stretching from slightly anterior of the eyes to the posterior end of the head, oval or convoluted in shape, usually damaged beyond recognition. *Collarette*—clear but very short. *Gut diverticulae*—absent. *Ovaries*—short and club-shaped, reaching no further than anterior end of posterior fins. *Vesiculae seminales*—small rounded knobs, touching tail fin and well separated from posterior fins. *Length*—up to 20 mm.

C. The Distribution of *S. enflata* in the Research Area.

As *S. enflata* is a typical warm water form, one would not expect to find it in large numbers in the cold Benguela current. It was, however, recorded during the first survey of the Benguela current by the *William Scoresby* (private communication). In the present collection, 75 specimens were found in the N70V and 19 in the N100H hauls (see Table VIII). A relatively large number of specimens (44) was only taken once, at station U, during July, 1954.

Vertical Distribution.—According to Thiel (1938), *S. enflata* occurs mainly in the 0–50 metres layer, its numbers decreasing rapidly as the depth of the water increases, and he gives 400 metres as an extreme barrier. Ritter-Zahony (1911a), describes it as an epiplanktonic form, while Thomson (1947) found that it was limited to the 100–0 metres layer. The closing-net hauls of R.S. *Africana II* show that this species can occur in the 600–400 metres layer, although not in large numbers. See the table below:—

Depth (metres).	April.	May.	June.	July.	August.	September.
600–400	—	—	—	—	2	—
400–200	—	—	1	—	—	—
200–0	1	—	2	1	1	3

The 19 specimens taken with the N100H net (See Table VIII), show that this species also exists at the surface during day-time.

(i) Horizontal Distribution on an Annual and on a Monthly Basis.

Too few specimens of this species were found to draw definite conclusions about its distribution. Graph XII shows its distribution by latitude and was plotted from the total annual occurrence per station (see Plate I for the latitudes on which the rows of stations lie). No specimens were found in station row N, O, J, E, B. The largest number, viz. 14, was found in the most southerly row of stations, R, H, G, T, and only 4 in row M, L, K, D, C. A slight decrease in numbers from south to north is therefore indicated.

What seems far more significant, is that 44 specimens were found at the most southerly station of the research area, station U, during July, 1954 only (see Plate I). During no other month of the year of observation was another specimen of *S. enflata* found at this station.

As *S. enflata* is a tropical form, one would expect to find it in the warm Agulhas current off the east coast. Unfortunately little could be found in the literature about the chaetognaths of the Agulhas current, although Cleve (1905) reports *S. enflata* as being common there in April and December. The large occurrence at station U, to the north-west of Table Bay during only one month, might therefore indicate an influx of warm Agulhas current water. If this can be proved, it is a strong indication that a vagary of the Agulhas current can round the Cape under certain conditions and mingle with the cold Benguela current water. More work will, however, have to be done to prove this theory, especially as the large occurrence at Station U was in July a winter

month when Agulhas flow is minimal under normal circumstances.

The Depth of the Water.—There is no indication that the depth of the water influences the distribution of this species.

The Temperature and Salinity of the Water.—It is difficult to correlate the occurrence of this species with the temperature and salinity of the water, as so few specimens were found. If the 44 specimens found at Station U during July, 1954, were brought there by an influx of water from the Agulhas current, then the higher temperature and salinity of this water would already have been lowered by mixing with the cooler water normally present in this area. Tables A and B show that the temperature and salinity at this station were 14·00°C and 35·17‰, respectively, when the samples were taken in July. These are the highest figures recorded at Station U during the year of observation (the yearly averages were 12·17°C and 34·95‰). This is a further indication that water from the Agulhas current could have reached Station U during this month.

Graph XIII was drawn to illustrate any trend which might indicate a correlation between occurrence and temperature. As so few specimens were found, each find was plotted against the temperature during that particular month, instead of using the annual occurrence and temperature averages as for the previous species. An attempt has already been made to explain the large occurrence at Station U. Not much may be learnt from the rest of this graph, except that no specimens were found at a temperature of less than 13·97°C which corresponds with a salinity of 35·21‰ (Station K, August, 1954), while the majority of finds were made in water with a temperature of more than 14·5°C. The lowest salinity at which *S. enflata* occurred was 35·08‰ at Station A in May, 1955.

The Density of other Plankton.—Too few specimens were found to correlate with the density of other plankton.

(ii) Horizontal distribution on a seasonal basis.

Although the largest number occurred during winter, this is only due to the 44 specimens found at Station U during July. There is no further indication of seasonal fluctuations in occurrence.

5. *Sagitta regularis* Aida (1897).

Sagitta regularis Aida (1897); Ritter–Zahony (1909a, 1910a, 1911a); Michael (1909, 1911, 1913); Oye (1918); Gray (1923); Burfield and Harvey (1926); Kuhl (1938); Tokioka (1939, 1940b, 1954a, 1954b); Thomson (1947); Ghirardelli (1947).

S. pseudoregularis Oye (1918).

A. Geographical Distribution.

Ritter–Zahony describes the distribution of *S. regularis* as Indo-pacific-tropical. During the *Gauss* Expedition it was found off Port Natal, thus in the Agulhas current, and also to the south-east of Madagascar. Thomson (1947) describes its distribution as follows: eastern and western Australia, California, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea. He does not record the species from South African waters.

B. Description.

This is a very small chaetognath. It has striking features such as the great development of the collarette and the marked regularity of the tactile organs. The eyes are large and are set wide apart. Its general appearance is strong and rigid and it appears to be somewhat stout as a result of the well-developed collarette.

Characters:—

Tail—28–34 per cent. *Anterior fins*—begin just behind ventral ganglion, become broader towards posterior, completely rayed. *Posterior fins*—about $\frac{2}{3}$ on tail, separate from anterior fins, completely rayed. *Hooks*—9–11. *Anterior teeth*—up to 4. *Posterior teeth*—up to 6. *Corona ciliata*—lies only on trunk, about $1\frac{1}{2}$ head lengths. *Collarette*—very well developed, nearly touching anterior fins. *Gut diverticulae*—present. *Ovaries*—sometimes stretch to anterior of ventral ganglion, ripe eggs of relatively large size. *Vesiculae seminales*—oval, touching posterior fins but separated from tail fin. *Length*—up to 7 mm.

C. The Distribution of *S. regularis* in the Research Area.

Vertical Distribution.—Burfield and Harvey (1926) describe this species as epiplanktonic as no significant catches were made from below 75 fathoms (138 metres) during the *Sealark* Expedition. Ritter–Zahony (1911a) regards it as a purely epiplanktonic form. Only two specimens were found in the closing-net hauls of R.S. *Africana II*, both in the 200–0 metres layer, one during June, 1955, the other during September, 1955

Horizontal Distribution.—Only 14 specimens were found in the N70V hauls, of which 8 were juveniles. These finds may be tabulated as follows. Juveniles are marked with a (J):—

Station.	Date.	Number.	Temp., °C. (0–50 metres).	Salinity, °/₀₀ (0–50 metres).
V	22/7/54	2 (J)	14·27	35·17
V	16/8/54	2 (J)	14·03	35·25
W	16/6/55	2 (J)	14·55	35·15
R	23/7/54	2	14·89	35·25
B	25/7/54	2	14·77	35·26
E	25/7/54	2 (J)	14·46	35·23
E	22/10/54	2	15·37	35·34

It will be noticed that:—

(*a*) The species was found at inshore Station R, as well as off-shore Stations B and E.

(*b*) Eight of the fourteen specimens were caught during July, 1954. (*Note* that the 44 specimens of *S. enflata* were caught at Station U on 22nd July, 1954.)

(*c*) Minimum temperature at which the species was found, was 14·03°C, while minimum salinity was 35·15°/₀₀.

(*d*) *S. regularis* was found only from mid-winter to mid-spring.

Again the question arises why a tropical Indo-pacific form such as *S. regularis* should be found in the cold Benguela current. It is interesting to note that this species was not found in the Benguela current by the *Meteor* or *William Scoresby* Expeditions, which indicates that it is not a regular inhabitant of these waters. Although only one report is available of this species in the Agulhas current, [Ritter–Zahony, (1911a)], it seems very likely that fair numbers should be found in that current. The fact that more than half the number of *S. regularis* taken during the year of observation should have been taken during the latter half of July, 1954, i.e. the same period when exceptionally large numbers of *S. enflata* occurred, seems to be another indication that a vagary of the Agulhas current rounded the Cape during that period.

Too few specimens are available to attempt a proper correlation with temperatures, salinities, settled volumes or the occurrence of pilchard eggs.

6. *Sagitta planctonis* Steinhaus (1896).

S. planctonis Ritter–Zahony (1909b, 1911a, 1911b, 1911c, 1914); Fowler (1905); Michael (1911, 1919); Johnston and Taylor (1921); Burfield and Harvey (1926); Burfield (1930); Germain (1930); Bollman (1934); John (1937); Kuhl (1938); Thiel (1938); Tokioka (1939, 1940a); Thomson (1947); Moore (1949); Fraser (1955); David (1956);

S. zetesios Fowler (1905); Michael (1909);

S. moreauensis Gray (1923).

Ritter–Zahony (1911a) combined *S. planctonis* Steinhaus (1896) and *S. zetesios* Fowler (1905) under the same name, *S. planctonis*. Although this arrangement remained until 1956, it has been suggested on both anatomical grounds (Tokioka 1939, George 1952), and on distributional grounds (Moore 1949), that two distinct forms are combined as one species. David (1956) investigated the matter and concluded that grouped under the one name *S. planctonis*, there are three distinct species, easily distinguishable when fully mature, but closely similar in the immature stages. These are:—

(*a*) the surface-living form of tropical and sub-tropical waters, originally named *S. planctonis* by Steinhaus;

(*b*) the deep water form also of warm latitudes, named *S. zetesios* by Fowler; and

(*c*) the Antarctic form described as *S. planctonis* by Ritter–Zahony, occurring from near the surface down to 1,500 metres or more, which David (1956) proposes to name *S. marri*.

A. Geographical Distribution (From David, 1956).

1. *Sagitta planctonis* Steinhaus (1896).

   Bermuda, S.E. Africa (Agulhas current area), Tasman Sea, off N.E. New Zealand, parts of the N. Atlantic. A surface living form breeding at a moderate depth (1,000–750 metres).

2. *Sagitta zetesios* Fowler (1905).

   A deep living form found in most oceans, but absent from the Antarctic.

3. *Sagitta marri* nov. sp.

   Probably a purely Antarctic form, extending from the surface down to about 1,500 metres, though commonest between 750 and 250 metres. Breeds in deep water.

B. Description.

For a full description of *S. planctonis*, *S. zetesios* and *S. marri*, refer to David (1956).

C. The Distribution of *S. planctonis* in the Research Area.

Only four specimens of *S. planctonis* were found during the year of observation in the N70V nets. All of these were taken in one haul at Station B on 18 August, 1954, at a temperature of 14·94°C and a salinity of 35·39°/$_{oo}$ (both integral means of 0–50 metres).

One specimen was taken at Station Y in the closing-net on 23 September, 1955, in the 600–400 metres layer.

All five of these specimens were juveniles and it was not possible to identify them according to the descriptions given by David (1956). They are therefore regarded as *S. planctonis* Steinhaus as described by Fraser (1952). This again suggests that a vagary of the Agulhas current has reached the Benguela current, but more evidence is required before this can be stated definitely.

7. *Sagitta hexaptera* d'Orbigny (1853).

S. hexaptera Aida (1897); Ritter–Zahony (1911a, 1911b, 1911c); Germain (1913); Jameson (1914); Germain and Joubin (1916); Oye (1918); Huntsman (1919); Johnston and Taylor (1921); Gray (1923); Bigelow (1926); Burfield and Harvey (1926); Burfield (1930); Bollman (1934); Fraser (1937); Kuhl (1938); Tokioka (1939, 1940a, 1940b); Thomson (1947); Fraser (1952).

S. magna Strodtmann (1892); Doncaster (1902); Cleve (1905).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution of *S. hexaptera* as follows: eastern Australia, New Zealand and South Pacific, California, China, Japan and Philippines, East Indies, Malaya, Pacific Islands, South Africa and southern Indian Ocean, Atlantic.

B. Description.

Too few specimens were available to compile an accurate list of characters. For a full description refer to Fraser (1952).

C. The Distribution of *S. hexaptera* in the Research Area.

Only two specimens were found in the N70V nets during the year of observation. They were both taken at station G, on 21st October, 1954, at an integral mean temperature and salinity of 15·54°C and 35·40°/$_{oo}$, respectively.

8. *Sagitta robusta* Doncaster (1902).

S. robusta Doncaster (1902); Ritter–Zahony (1909a, 1909b, 1910a, 1910c, 1911a, 1911c); Jameson (1914); Oye (1918); Johnston and Taylor (1919); Gray (1923); Burfield and Harvey (1926); Burfield (1930); John (1933, 1937); Kuhl (1938); Thomson (1947);

S. ferox Fowler (1906); Michael (1909, 1913, 1919).

S. ai Tokioka (1939, 1940a, 1940b).

S. planctonis Delsman (1939).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution of this species as follows: eastern and western Australia, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea.

B. Description.

The specimens were identified according to the descriptions of Ritter–Zahony (1911a) and Burfield and Harvey (1926).

C. The Distribution of *S. robusta* in the Research Area.

No specimens were found in the N70V hauls during the year of observation. One specimen was found in the N100H haul at Station A on 22 May, 1955. The surface temperature and salinity were 17·03°C and 35·30°/$_{oo}$, respectively.

Two specimens were taken with the closing-net at Station Y in the 200–0 metres layer, one on 17th June, 1955, the other on 23rd September, 1955. Judging from these few specimens, it seems to be an epiplanktonic, warm water form, which agrees with Ritter–Zahony's and Burfield's and Harvey's results. Again it is interesting to note that this is a species not normally encountered in the South Atlantic although it is common in the Indian Ocean.

9. *Sagitta neglecta* Aida (1897).

S. neglecta Aida (1897); Michael (1909, 1911, 1919); Ritter–Zahony (1911a, 1911c); Germain and Joubin (1916); Oye (1918); Johnston and Taylor (1919); Gray (1923); Burfield and Harvey (1926); John (1933, 1937); Kuhl (1938); Tokioka (1939, 1940b); Thomson (1947);

S. hispida Doncaster (1902);

S. trichodermis Oye (1918).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution of *S. neglecta* as follows: eastern Australia, California, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea, South Africa, Southern Indian Ocean. Ritter–Zahony (1911a) reports that the species was found in the Agulhas current off Port Natal, and describes it as an Indo-pacific-tropical and purely epiplanktonic form. Burfield and Harvey (1926) agree with this description. No records of finds of this species in the Atlantic Ocean or Benguela current could be found.

B. Description.

The specimens were identified according to the description of Burfield and Harvey (1926).

C. The Distribution of *S. neglecta* in the Research Area.

Only four specimens were found in the N70V nets during the year of observation. Two were caught at Station H on 23rd September, 1954, and two at Station B on 18th February, 1955. The integral means of the temperature and salinity of the 0–50 metres layer were as follows: Station H—14·94°C and 35·36‰, respectively; Station B—15·10°C and 35·19‰, respectively.

Three specimens were taken in the closing-net at Station Y on 24 August, 1955, from a depth of 400–200 metres.

S. neglecta is therefore another Indo-pacific form, the presence of which in the Benguela current is of interest.

10. *Pterosagitta draco* Krohn (1853).

Pt. draco Ritter–Zahony (1911a, 1911b, 1911c); Germain and Joubin (1916); Oye (1918); Michael (1919); Huntsman (1919); Johnston and Taylor (1919); Burfield and Harvey (1926); Bollman (1934); Kuhl (1938); Tokioka (1939, 1940a, 1940b, 1954a, 1954b); Thomson (1947); Ghirardelli (1947, 1950); Fraser (1952);

Spadella draco Aida (1897); Doncaster (1902, 1903); Ritter–Zahony (1910a); Michael (1909, 1911).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution of *Pt. draco* as follows: eastern and western Australia, California, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea. According to Ritter–Zahony, this species occurs regularly in the epiplankton of the Atlantic between 40°N. and 40°S. Thiel (1938) states that there is an area of maximum abundance in the South Atlantic between 25°S. and 35°S. and mentions that this species was found close to the west coast of South Africa at approximately 28°S., i.e. in the Benguela current, but north of the research area of R.S. *Africana II*. He regards 100–50 metres as the layer in which this species has its maximum abundance. Jameson (1914) states that *Pt. draco* is a typically tropical and sub-tropical form, which although distinctly epiplanktonic does not occur at the surface but some little way down.

B. Description.

The specimens were identified according to the descriptions of Ritter–Zahony (1911a) and Tokioka (1940a). It is easily distinguishable by the extreme development of the collarette, although care has to be taken when identifying, as the collarette is frequently partly or completely missing, due to damage in the plankton net. Another character of this species is that the anterior fins and the trunk part of the posterior fins are absent, apparently having been replaced by the voluminous collarette. Thus there is only one pair of lateral fins, which are rounded, completely rayed and stretching over about $\frac{2}{3}$ of the tail segment.

C. The Occurrence of *Pt. draco* in the Research Area.

The occurrence of *Pt. draco* in the research area during the year of observation is shown in Table IX. All the catches were made with the N70V

net and the temperatures and salinities are the integral means of the 0–50 metres layer. No specimens were found in the N100H hauls. It appears, therefore, that this species did not occur at the surface during the period of observation, a fact which agrees with the observations of other workers.

From Table IX it can be seen that 52 specimens were taken with the N70V nets. As this is a warm water species, one would not expect to find it at the cool inshore stations. This cannot be established from the available data as specimens were found at Stations R and O. If the integral means for the 0–50 metres layer are taken, the temperature range in which the specimens were found is 12·65–17·05°C. In the same way the salinity range is 35·00–35·41‰. The species occurred mostly in the months of July to November, i.e. from mid-winter to the end of spring. The only exceptions are the two specimens taken during February at Station W. As the prevalence of S.E. winds during summer usually causes upwelling of very cold water, one would not expect to find a warm water species such as *Pt. draco* during this season. It is interesting, therefore, that the temperature of the 0–50 metres layer was exceptionally high at Station W on 16th February, 1955 (17·05°C).

As so few specimens are available, it is not possible to draw definite conclusions about the relationship between the occurrence of this species and other factors such as the temperature and salinity of the water, the density of other plankton or the occurrence of pilchard eggs.

On 23rd September, 1955, 7 specimens were taken at Station Y with the closing-net in the 200–0 metres layer. No other specimens of this species were found in the closing-nets.

11. *Eukrohnia hamata* Möbius (1875).

E. hamata Ritter–Zahony (1909b, 1910b, 1911a, 1911b, 1911c, 1914); Michael (1913, 1919); Jameson (1914); Germain and Joubin (1916); Huntsman (1919); Johnston and Taylor (1921); Bigelow (1926); Burfield and Harvey (1926); Russel (1927, 1939); Bollman (1934); Kuhl (1938); Thiel (1938); Tokioka (1939); Thomson (1947); Fraser (1952);

Krohnia hamata Cleve (1905); Michael (1909); Shipley (1910).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution of *E. hamata* as follows: eastern Australia, New Zealand, South Pacific, California, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea and the Atlantic Ocean. Ritter–Zahony regards it as a cosmopolitan, mesoplanktonic form. Thiel (1938) describes the distribution of this species in the Atlantic Ocean and shows that it occurs mainly at the surface in Antarctic waters. Towards the equator it gradually sinks to greater depths and only reappears in smaller depths north of the equator. Further he states that it occurs in largest numbers in the area between 45°S. and 35°S. (although it is still common farther to the south), and that it is common in the Benguela current.

B. Description.

The specimens were identified according to the descriptions of Ritter–Zahony (1911a, 1911c), Burfield and Harvey (1926) and Fraser (1952). Thomson (1947) regards *E. richardi* and *E. fowleri* as synonymous with *E. hamata*. Whether this is correct could not be judged, as only juveniles were found in the present collection.

C. The Occurrence of *E. hamata* in the Research Area.

Only 16 juvenile specimens were found in the N70V nets, so that too few specimens were available to warrant correlation with the temperature and salinity of the water (see the table below):—

Date.	Station.	Depth (metres).	Number of Specimens.	Temp. °C.	Salinity, ‰.
24/11/54	X	150	4	11·92	34·85
23/9/54	T	370	2	14·76	35·35
25/11/54	T	370	2	14·57	35·17
25/7/54	D	250	2	14·44	35·22
27/11/54	J	210	4	12·15	34·94
24/4/55	J	210	2	12·55	34·96

E. hamata is probably a deeper-living form which occurs mainly at depths greater than 100 metres. This is shown by the fact that it occurred in relatively large numbers in the closing-net hauls taken at Station Y (see the table below):—

Depth (metres).	April.	May.	June.	July.	August.	September.	Total.
600–400	6	—	—	1	—	11	18
400–200	12	4	3	2	2	3	26
200–0	2	—	1	1	2	—	6

These specimens were all juveniles and although no definite conclusions can be based upon this table, it appears that *E. hamata* occurred in greatest density at a depth of 400–200 metres.

12. *Krohnitta subtilis* Grassi (1881).

Krohnitta subtilis Ritter-Zahony (1910a, 1910c, 1911a, 1911b, 1911c); Michael (1919); Jameson (1914); Germain and Joubin (1916); Oye (1918); Huntsman (1919); Johnston and Taylor (1919); Burfield and Harvey (1926); Burfield (1930); Germain (1930); Bollman (1934); Kuhl (1938); Tokioka (1939, 1940a, 1940b, 1954a); Thomson (1947); Fraser (1952);

Krohnia subtilis Michael (1909); Shipley (1910); *Eukrohnia subtilis* Michael (1911).

A. Geographical Distribution.

Thomson (1947) describes the geographical distribution as follows: eastern and western Australia, California, China, Japan, Philippines, East Indies, Malaya, Pacific Islands, North Indian Ocean, Red Sea and the Atlantic Ocean.

Ritter–Zahony (1911a), regards *K. subtilis* as a tropical-subtropical form, although he found a single specimen in the Antarctic at 66°S. He suggested that this species goes through its first stages of development in the upper, warmer water layers and then gradually sinks to the deeper, cooler layers. Thiel (1938) states that the most southerly limits of distribution lie just to the south of Cape Town and in the Bass Strait, south of Australia. He regards the main distribution area as lying between the 25°C and 20°C isotherms. Bumpus and Lowe-Pierce (1955) found the species regularly off North Carolina in water with a salinity of 36°/$_{oo}$ or more.

B. Description.

The specimens were identified according to the descriptions and figures of Ritter-Zahony (1911a), Burfield and Harvey (1926), Tokioka (1940a, 1940b), Thomson (1947) and Fraser (1952).

There seems to be considerable doubt whether *K. subtilis* Grassi and *K. pacifica* Aida should be regarded as separate species or not. Burfield and Harvey (1926) agree with Ritter–Zahony's (1911a) contention, that *K. subtilis* and *K. pacifica* belong to one and the same species with a large vertical distribution. *K. pacifica* is then the smaller surface or epiplanktonic form, which becomes sexually mature more quickly as a result of the higher temperature of the upper water layers. Tokioka described both forms and definitely regards them as two separate species. Thomson (1947) agrees with Tokioka on the following basis. *K. subtilis* is one of the most slender chaetognaths, while *K. pacifica* is distinctly broader. At the same length, *K. pacifica* tends to have more hooks and teeth than *K. subtilis*. The ovaries are very short even in fully mature *K. subtilis*, but are elongated, reaching beyond the anterior end of the lateral fins in *K. pacifica*. A further difference is in the shape of the lateral fins which are far more rounded in the case of *K. subtilis* but have not got a prominent posterior point which seems to overlap the seminal vesical as in *K. pacifica*.

In view of these differences, the specimens found in the present collection are definitely regarded as belonging to a separate species—*K. subtilis*.

C. The Distribution of *K. subtilis* in the Research Area.

Only ten specimens were taken in the N70V nets during the year of observation, all of which were either juvenile or just beginning their sexual development (see the table below):—

Date.	Station.	Depth (metres).	Number of Specimens.	Temperature °C.	Salinity, °/$_{oo}$.
23/9/54	H	290	2	14·94	35·36
17/6/55	H	290	2	13·93	35·13
17/6/55	G	380	2	14·35	35·14
25/11/54	S	360	2	15·67	35·36
25/7/54	C	360	2	14·87	35·30

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Too few specimens were therefore available for correlation purposes.

Only two specimens were captured in the closing-net at Station Y, one on 22nd April, 1955, the other on 24th August, 1955. Both were taken from the 200–0 metres layer.

VII. TREATMENT OF DATA ON A STATISTICAL BASIS.

A description of the statistical methods used may be found in Edwards (1951).

1. Correlation of the Temperature and Salinity of the Water.

The temperature and salinity values used for correlation purposes, are the integral means of the 0–50 metres layer. These values are given for each station and for every month of the year of observation in Tables A and B. In the bottom row of each of these tables, the integral means for each station during the 12 months of observation, are averaged. These average values were used for the correlation of the temperatures and salinities of the water.

The same average temperature and salinity values are plotted on scatter diagram I. A rectilinear relationship is indicated. The intervals are 0·5°C for the temperatures, and 0·05‰ for the salinities. With the figures derived from this scatter diagram, calculation I was made, and the highly significant figure of r=0·984, obtained.

2. Correlation of the Occurrence of *S. friderici* and the Temperature of the Water.

Graph XIV is a correlation chart on which the occurrence of *S. friderici* and the water temperature at each station during the year of observation have been plotted, using the totals and averages of Tables I and A, respectively. The relationship in the 10·0°–14·0°C temperature range appears to be close to rectilinear. In the 10·0°–16·0°C range, the relationship appears to be curvilinear. It should be noted that all the stations in the 14·0°–16·0°C range are off-shore stations and, as has already been shown, *S. friderici* is an inshore species of which only small numbers occur in the off-shore water with an average temperature of more than 13·0°C. This is also evident in Graph XIV. The relatively large proportion of off-shore stations, where only small numbers of *S. friderici* occur, as seen in this graph, seems to stress the abundance in the off-shore water unduly. For this reason, two coefficients of correlation have been calculated, one for the 10·0°–16·0°C range, and the other for the 10·0°–14·0°C range, thus omitting the off-shore stations C, B, A, T, W, D, E, F, G and H.

Two methods of calculation were employed. The 10·0°–16·0°C range calculation was computed from a scatter diagram, and r=–0·793. The 10·0°–14·0°C range calculation was a correlation using original measurements. In this case r=–0·826 (see calculation II). Both these figures are significant on a 1 per cent level, although 20 degrees of freedom could be used for the first, but only 10 degrees for the second.

3. Correlation of the Occurrence of *S. minima* and the Temperature of the Water.

On Graph XV the occurrence of *S. minima* and the average water temperature values have been plotted. A rectilinear relationship is indicated. A calculation using the same method as for calculation II, but including all the stations, showed that r=0·751. This is also significant on a 1 per cent level.

VIII. DISCUSSION.

(*a*) Chaetognaths as Indicators of Hydrological Conditions in the Research Area.

It has been shown that various species of chaetognaths in the research area may be expected to be found in water with various characteristics. The question is whether each of these species may be regarded as a reliable indicator of the type of water in which it normally occurs in largest numbers. For this reason an attempt has been made to show which are warm and which are cold water forms, and to associate stenothermic forms with the warm off-shore and the cool inshore water. Thus *S. friderici* and *S. minima* may be useful as indicators in water with a temperature range similar to that of the research area, while a eurythermal form such as *S. serratodentata* cannot. Obviously a relatively large number of specimens must be available to obtain significant results.

On the basis of the data obtained for the research period, only two species satisfy the above requirements, namely *S. friderici* and *S. minima*. Possibly an analysis of the catches of later years will increase this number.

As has been shown, *S. friderici* is typical of cold, inshore water with much zooplankton, while *S. minima* prefers the warmer off-shore water.

On this basis it seems likely that if a dense patch of *S. friderici* were found at Station D it would suggest that inshore water had moved to D, even if the temperature had increased in the process. This would be a valuable guide to hydrological work.

It must be remembered, however, that these deductions are based on only one year's observations. In order to be able to draw definite conclusions, this work would have to be extended over a research period of a number of years.

It must be kept in mind that no factor on its own (e.g. depth of water, its temperature and salinity, or the density of other plankton), can control the occurrence of a species. *S. friderici* never occurred in large numbers in the research area when the average water temperature was above 13°C. From Graph II and Table III it can be seen that during winter the water temperature was below 13°C at Stations L, M and N, all of which have a depth of less than 200 metres. In spite of this the numbers of *S. friderici* found during winter are very small, probably because the density of other zooplankton is low during this season (settled volumes below 10 c.c.). This again is likely to have been caused by a lack of phytoplankton due to the small amount of sunshine during winter. The importance of each factor investigated, has to be seen in relation to that of all the other factors which together are characteristic of a mass of water. This does not, however, detract from the value of correlations which can be established, such as occurrence and water temperature. These principles are applicable to any indicator species.

The exceptionally large catch of *S. enflata* at Station U on 22nd July, 1954, is of special interest, especially as Station U is the most southerly station in the research area, and an influx of Agulhas current water would not be " diluted " too much at this station. There is further evidence that an influx of Agulhas current water reached the Benguela current during July, 1954. Ten specimens of *S. enflata* were found at other stations during that month, which is more than found in the research area during any other month of the year of observation (see Table VIII). Further, 8 of the 14 specimens of *S. regularis* which were taken during the year of observation, were captured during July, 1954, and *S. regularis* is also an Indo-pacific form which has been recorded from the Agulhas current but not from the Benguela current. Two other species which are of special interest for the same reason are *S. robusta* and *S. neglecta*, but only very few of these were captured.

In order to be able to compare the efficiency of various species as indicator forms, coefficients of correlation were calculated. When correlating water temperature and occurrence, it was found that only *S. friderici* and *S. minima* can be used as reliable indicators within the research area, and that *S. friderici's* efficiency as such is slightly higher than that of *S. minima*. *S. serratodentata*, the only other species which occurred in sufficiently large numbers for statistical correlation, is obviously useless as an indicator within the temperature range of the research area.

(*b*) The Relationship between the Occurrence of Various Species of Chaetognaths and Pilchard Eggs.

The occurrence and distribution of eggs of a species of fish which is caught on a large scale such as the South African pilchard, *Sardinops ocellata*, are of importance not only for research purposes, but also for the industry itself. It would therefore be valuable if another form of planktonic life could be found, which is associated with the occurrence of pilchard eggs, or which can indicate conditions in which they are likely to be found. Such an " indicator form " should be easily visible, occur in sufficient numbers and should be easy to identify accurately. Chaetognaths are suitable as indicator forms and an attempt was made to find a correlation between the occurrence of pilchard eggs and the occurrence of various species of *Chaetognatha*. As Graph IV shows, no such correlation could be established, but it is hoped that further work in this direction will yield more satisfying results.

(*c*) Voluntary Migrations of *Chaetognatha*.

Another question is to what extent the animal's own propulsion can account for the accumulation of a species in water with favourable conditions for its existence. Chaetognaths are capable of very rapid, darting movements in the water. Although these rapid movements are suitable for catching prey, it is doubtful whether they can be kept up long enough for sustained horizontal migrations. It seems more likely that the *Chaetognatha* follow the movements of the organisms upon which they prey, and that this partly explains the vertical migrations to the surface at night, in keeping with most of the zooplankton. In spite of this, the power of voluntary movements of small animals such as chaetognaths must be limited and it is likely that they can easily be carried from one locality to another by sea currents.

(d) The Relationship between Commercially Important Species of Fish and Chaetognaths.

Chaetognaths can be of importance to a fish population in two ways:—

(i) They may be preyed upon by young and adult fish.

(ii) They can do damage to the stocks of fish eggs and larvae.

Among the species of fish which are of commercial importance in the research area, are the pilchard (*Sardinops ocellata*) and the maasbanker (*Trachurus trachurus*). The examination of the stomach contents of these two species was part of the author's routine activities as a field biologist of the Division of Fisheries at Stompneus Bay. Although no detailed records of the chaetognaths found in fish stomachs were kept, the following may be stated. Remains of chaetognaths are rarely found in the stomach contents of pilchards, although copepods are frequently eaten by these fish. Maasbanker stomachs, on the other hand, are occasionally packed with chaetognaths, especially *S. friderici* and to a smaller extent, *S. serratodentata.* It therefore seems certain that chaetognaths are of practically no value as food for the pilchard, but can be an important constituent of the food of the maasbanker.

As far as the second point is concerned, not much evidence could be found in the present collection. Although a number of specimens of *S. friderici* were found with larvae of clupeoid or other fish between their seizing jaws, none was found with fish larvae in its gut. In spite of this it seems likely that chaetognaths can do extensive damage to stocks of larval fish, especially if they occur in large numbers, as *S. friderici* sometimes does. This was also suggested by Lebour (1923) in the case of larval herrings in the English Channel.

In conclusion it may be said that there remains much scope for further research in this direction. It is necessary that similar work should be done in the waters of the east coast, so that the exact relationship between the chaetognath faunas of the Agulhas and Benguela currents can be determined. The research period should stretch over a number of years to make comparisons on an annual basis possible.

An attempt can also be made to determine whether there is a relationship between the occurrence of chaetognaths and the larvae of pilchards, maasbankers and other types of fish, as large numbers of chaetognaths might do considerable damage to the stocks of larval fish.

An investigation of the relationship between the occurrence of chaetognaths and other types of zooplankton would also be useful.

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Table A.

Integral Mean Temperatures of the 0–50 Metres Layer in °C.

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.
July.....	14·00	14·27	15·16	13·93	14·89	14·77	14·94	15·13	15·03	14·23	14·39	14·60	15·03	12·69	14·44	14·91	14·46	14·77	11·67	13·24	14·03	14·44	14·87
August.....	13·16	14·03	14·40	13·59	13·72	14·16	14·42	14·56	14·53	13·49	14·04	14·22	14·45	12·38	12·97	14·23	13·77	14·94	13·11	13·45	13·97	13·96	14·25
September.....	13·30	14·60	15·07	14·65	13·41	14·94	14·93	14·76	14·77	11·62	14·81	14·75	14·86	11·27	12·79	14·49	14·67	14·65	10·49	12·22	12·80	14·89	15·10
October.....	13·17	15·82	16·49	13·47	13·58	15·23	15·54	16·16	16·08	11·53	14·13	15·27	16·17	10·14	12·65	12·68	15·37	15·67	9·67	12·07	12·65	15·09	15·80
November.....	11·94	13·37	14·95	11·92	12·00	13·88	14·44	14·57	15·67	9·59	14·65	16·71	17·17	10·15	10·15	12·15	13·51	15·71	9·79	10·74	12·97	14·86	16·90
December.....	13·76	13·93	16·01	13·64	12·82	16·50	16·99	17·06	17·40	10·89	15·51	17·24	17·33	10·67	11·17	13·54	14·71	16·01	9·76	11·22	12·19	13·97	15·95
January.....	10·41	12·59	17·59	10·83	10·73	12·05	14·26	16·33	14·41	10·81	12·94	14·71	13·96	11·12	12·15	13·16	14·18	14·33	10·37	12·54	12·68	13·55	14·83
February.....	10·38	11·41	17·05	10·87	10·74	11·85	11·84	17·37	16·00	10·63	12·45	13·09	14·91	10·77	11·79	12·96	14·64	15·10	11·19	11·39	12·19	14·44	14·60
March.....	11·18	12·65	14·13	11·85	11·09	13·61	14·24	14·13	15·59	10·81	12·87	14·02	14·44	10·02	11·92	13·86	14·15	15·63	9·90	11·57	12·77	13·71	14·31
April.....	10·71	12·27	17·00	12·65	11·35	16·21	16·70	16·80	—	11·64	11·90	16·37	17·38	10·55	12·21	12·55	15·64	14·84	11·79	11·12	12·43	15·88	16·42
May.....	11·64	12·23	15·13	12·09	11·34	11·86	14·73	14·86	—	10·60	13·45	14·40	15·07	10·70	11·41	13·55	13·96	15·07	10·95	11·47	12·78	13·42	15·18
June.....	12·33	12·78	14·55	11·13	10·50	13·93	14·35	15·23	—	10·95	12·04	13·46	15·54	10·62	11·16	12·57	13·19	15·01	10·81	12·04	12·24	13·51	14·71
	12·17	13·33	15·63	12·55	12·18	14·08	14·78	15·58	15·50	11·40	13·60	14·90	15·53	10·92	12·07	13·39	14·35	15·14	10·79	11·92	12·81	14·31	15·24

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Table B.

Integral Mean Salinities of the 0–50 Metres Layer in ‰.

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O	J.	E.	B.	M.	L.	K.	D.	C.
July	35·17	35·17	35·35	35·16	35·25	35·29	35·35	35·35	35·35	35·20	35·21	35·24	35·29	34·88	35·25	35·34	35·23	35·26	34·63	35·06	35·17	35·22	35·30
August	35·11	35·25	35·32	35·16	35·19	35·27	35·30	35·34	35·32	35·17	35·26	35·28	35·32	34·96	35·09	35·27	35·15	35·39	34·94	35·11	35·21	35·15	35·27
September	35·12	35·29	35·36	35·31	34·97	35·36	35·36	35·35	35·35	34·83	35·35	35·35	35·35	34·77	35·01	35·33	35·32	35·35	34·77	34·95	35·00	35·35	35·35
October	35·09	35·37	35·43	35·11	35·17	35·35	35·40	35·46	35·46	34·80	35·14	35·31	35·43	34·69	34·95	34·96	35·34	35·34	34·72	34·93	35·07	35·29	35·40
November	34·89	35·12	35·18	34·85	34·75	35·12	35·18	35·17	35·36	34·69	35·23	35·41	35·39	34·66	34·72	34·94	35·03	35·26	34·69	34·72	34·94	35·09	35·42
December	35·08	35·04	35·18	34·99	34·96	35·30	35·32	35·32	35·33	34·70	35·29	35·36	35·34	34·69	34·70	35·13	35·06	35·23	34·66	34·71	34·79	35·04	35·25
January	34·77	34·95	35·40	34·76	34·71	34·86	35·17	35·38	35·19	34·72	34·95	35·04	35·03	34·71	34·82	34·92	35·04	35·06	34·71	34·74	34·92	34·97	35·21
February	34·73	34·76	35·31	34·72	34·69	34·76	35·08	35·35	35·17	34·70	34·93	34·92	35·23	34·77	34·77	34·89	34·94	35·19	34·75	34·75	34·80	34·89	34·92
March	34·75	34·83	35·08	34·76	34·75	34·83	35·04	35·08	34·98	34·72	34·87	34·87	35·03	34·75	34·77	34·86	35·04	35·19	34·76	34·77	34·86	34·87	35·08
April	34·80	34·96	35·34	34·96	34·77	35·25	35·25	35·33	—	34·85	34·91	35·24	35·36	34·72	34·93	34·96	35·20	35·06	34·75	34·77	34·89	35·20	35·23
May	34·91	34·94	35·25	34·93	34·85	34·92	35·13	35·19	—	34·77	35·01	35·13	35·08	34·76	34·83	35·04	35·07	35·08	34·79	34·83	34·89	35·06	35·16
June	34·95	35·03	35·15	34·76	34·74	35·13	35·14	35·22	—	34·78	34·91	35·03	35·20	34·75	34·78	34·96	34·97	35·17	34·73	34·75	34·79	34·99	35·16
	34·95	35·06	35·28	34·96	34·90	35·12	35·23	35·29	35·28	34·83	35·09	35·18	35·25	34·76	34·89	35·05	35·12	35·22	34·74	34·84	34·94	35·09	35·23

Table I.

Sagitta friderici N70V.

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.	Total.
July.....	198	6	0	36	20	16	0	0	0	0	20	14	4	0	10	2	0	2	0	26	24	48	4	430
August.....	2	2	0	4	2	0	0	0	0	0	0	2	0	2	4	4	8	0	8	0	4	6	0	48
September.....	68	0	0	0	58	10	0	0	0	150	6	2	0	14	16	0	6	0	8	16	10	0	0	364
October.....	4	0	0	16	16	0	0	0	0	40	14	0	0	224	12	6	0	0	220	98	0	0	0	650
November.....	6	2	78	30	6	5	14	22	0	0	0	6	4	44	10	28	0	6	0	90	16	0	2	369
December.....	34	48	8	10	4	6	22	0	4	12	2	8	0	18	10	10	52	6	354	76	26	8	0	718
January.....	4	4	8	0	176	8	0	0	14	58	4	4	28	30	20	0	0	2	700	92	104	4	2	1,262
February.....	4	0	4	56	440	30	12	0	3	120	0	0	7	0	22	0	0	2	46	200	0	0	0	946
March.....	6	8	20	0	36	2	14	4	12	260	2	0	9	270	84	0	0	0	156	220	120	2	4	1,229
April.....	2	0	0	0	0	0	0	0	—*	0	0	0	0	44	0	0	0	0	448	240	46	2	0	782
May.....	0	6	10	140	38	38	0	20	—*	376	2	4	10	16	200	2	8	10	90	150	198	0	10	1,328
June.....	0	0	0	128	20	16	10	2	—*	400	2	2	0	10	250	2	0	0	0	2	8	0	2	854
Total.....	328	76	128	420	816	131	72	48	33	1,416	52	42	62	672	638	54	74	28	2,030	1,210	556	70	24	8,980

* Station S was discontinued from April, 1955.

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Table II.—*S. friderici* N100H.

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.	P.	Total.
January.....	0	0	1	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	40	0	18	0	0	193
February.....	25	0	1	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	76
March.....	0	1	3	0	8	0	0	0	0	28	1	1	0	95	2	0	0	0	42	10	7	0	6	2,778	2,982
April.....	0	0	1	0	81	5	0	0	—	0	0	0	0	54	0	0	0	0	10	0	0	0	0	0	151
May.....	0	0	0	254	1	0	0	14	—	6	9	0	6	0	175	0	1	499	0	25	11	2	9	975	1,987
TOTAL.....	25	1	6	308	126	5	0	14	0	34	10	1	6	149	177	0	1	499	132	89	18	20	15	3,753	5,389

Table III.—*S. friderici.*

Spring } September. October. November. ——— Summer } December. January. February. - - - - - Autumn } March. April. May. -·-·-·-· Winter } June. July. August. · · · · ·

Station.	Depth. (Metres).	Occurrence.	Mean Temp. °C.	Mean S.V. c.c.	Occurrence.	Mean Temp. °C.	Mean S.V. c.c.	Occurrence	Mean Temp. °C.	Mean S.V. c.c.	Occurrence.	Mean Temp. °C.	Mean S.V. c.c.
R.....	140	80	13·00	16·7	620	11·43	43·7	74	11·26	44·0	42	13·04	14·7
H.....	290	15	14·68	11·7	44	13·47	13·0	40	13·89	11·0	32	14·29	2·7
G.....	380	14	14·97	14·3	34	14·36	10·0	14	15·22	11·3	10	14·57	2·7
T.....	370	22	15·16	12·3	0	16·92	6·3	24	15·26	5·3	2	14·97	3·3
Averages.....		33	14·45	13·8	174	14·04	18·2	38	13·91	17·9	26	14·22	5·8
Q.....	110	190	10·91	23·5	190	10·78	18·0	636	11·02	42·0	400	12·89	10·7
I.....	260	20	14·53	11·3	6	13·63	9·7	4	12·74	6·7	22	13·49	2·3
F.....	300	8	15·58	7·3	12	15·01	11·3	4	14·93	5·0	18	14·09	4·3
A.....	420	4	16·07	10·7	35	15·40	5·7	19	15·63	7·7	4	15·01	2·3
Averages.....		55	14·27	13·2	61	13·70	11·2	166	13·58	15·3	111	13·87	4·9
N.....	80	282	10·52	15·3	48	10·85	12·0	330	10·42	15·3	12	11·90	5·3
O.....	160	38	11·86	12·0	52	11·70	20·3	284	11·85	26·0	264	12·86	10·3
J.....	210	34	13·11	12·7	10	13·22	17·0	2	13·32	7·7	8	13·90	3·3
E.....	290	6	14·52	9·0	52	14·51	10·3	8	14·58	11·7	8	13·81	3·7
B.....	380	6	15·34	16·0	10	15·15	9·3	10	15·18	7·0	2	14·91	3·0
Averages.....		91	13·07	13·0	34	13·09	13·8	127	13·07	13·5	24	13·48	5·1
M.....	80	228	9·98	10·7	1,100	10·44	19·3	694	10·88	46·7	8	11·86	3·3
L.....	130	204	11·68	15·0	368	11·72	23·0	610	11·39	30·0	28	12·91	6·0
K.....	170	26	12·81	12·0	130	12·35	11·7	364	12·66	23·0	36	13·41	10·0
D.....	250	0	14·95	8·3	12	13·99	8·3	4	14·34	6·0	54	13·97	4·7
C.....	360	2	15·93	7·7	2	15·13	6·7	14	15·30	6·0	6	14·61	4·7
Averages.....		92	13·07	10·7	322	12·73	13·8	337	12·91	22·3	26	13·35	5·7
Grand Average.....		66	13·64	12·6	151	13·34	14·2	174	13·33	17·4	53	13·69	5·4

Table IV.

S. minima N70V.

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.	Total.
July.....	88	2	14	30	20	30	10	24	36	10	14	24	8	2	24	8	14	22	0	16	2	14	2	414
August.....	4	22	16	50	18	20	10	16	26	0	16	50	18	2	8	22	20	4	4	4	12	18	26	386
September.....	4	8	8	8	0	12	32	28	28	4	20	64	18	0	4	14	18	28	0	10	6	20	36	370
October.....	0	4	12	2	4	8	14	16	4	2	4	6	10	0	2	14	12	8	0	2	8	2	2	136
November.....	0	4	4	0	0	0	0	0	6	0	4	4	26	0	0	4	0	8	2	4	4	2	1	73
December.....	8	8	0	0	0	28	44	0	14	0	12	24	2	0	0	2	10	6	0	0	4	14	4	180
January.....	0	0	0	0	0	0	0	6	20	0	0	4	10	0	0	2	4	0	0	0	4	4	2	56
February.....	0	0	24	0	0	0	40	16	7	0	0	4	6	0	0	0	0	12	0	0	0	0	6	115
March.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	2	16
April.....	0	2	2	0	0	2	4	2	—	0	0	0	2	2	0	0	0	0	0	0	0	2	0	18
May.....	0	0	0	0	0	0	0	2	—	0	0	2	2	0	0	0	0	0	0	0	0	0	10	16
June.....	0	0	2	0	0	10	2	0	—	0	0	0	10	0	0	0	0	0	0	0	2	0	2	28
Total.....	104	50	82	90	42	110	156	110	141	16	70	182	112	6	38	66	78	102	6	36	42	76	93	1,808

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Table V.

S. minima.

Station.	Depth (Metres.)	Spring (September. October. November.) Occurrence.	Mean Temp. C.	Summer (December. January. February.) Occurrence.	Mean Temp. C.	Autumn (March. April. May.) Occurrence.	Mean. Temp. C.	Winter (June. July. August.) Occurrence.	Mean Temp. C.
R	140	4	13·00	0	11·43	0	11·26	38	13·04
H	290	20	14·68	28	13·47	2	13·89	60	14·29
G	380	46	14·97	84	14·36	4	15·22	22	14·57
T	370	44	15·16	22	16·92	4	15·26	40	14·97
Average		29	14·45	34	14·04	3	13·91	40	14·22
Q	110	6	10·91	0	10·78	0	11·02	10	12·89
I	260	28	14·53	12	13·63	0	12·74	30	13·49
F	300	74	15·58	32	15·01	2	14·93	74	14·09
A	420	54	16·07	18	15·40	4	15·63	36	15·01
Average		41	14·27	16	13·70	2	13·58	38	13·87
N	80	0	10·52	0	10·85	2	10·42	4	11·90
O	160	6	11·86	0	11·70	0	11·85	32	12·86
J	210	32	13·11	4	13·22	0	13·32	30	13·90
E	290	30	14·52	14	14·51	0	14·58	34	13·81
B	380	44	15·34	18	15·15	14	15·18	26	14·91
Average		22	13·07	7	13·09	3	13·07	25	13·48
M	80	2	9·98	0	10·44	0	10·88	4	11·86
L	130	16	11·68	0	11·72	0	11·39	20	12·91
K	170	18	12·81	8	12·35	0	12·66	16	13·41
D	250	24	14·95	18	13·99	2	14·34	32	13·97
C	360	39	15·93	12	15·13	12	15·30	30	14·61
Average		20	13·07	8	12·73	3	12·91	20	13·35
Grand Average		27	13·64	15	13·34	3	13·33	30	13·69

Table VI.

S. serratodentata N70V and N100H (numbers taken in N100H-net given in brackets).

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.	Total.
July.....	0	0	0	0	0	0	8	10	4	0	0	0	0	0	2	0	0	0	0	2	14	2	0	42
August.....	0	0	0	14	0	2	0	4	14	0	0	8	10	0	2	4	2	4	0	0	0	0	2	66
September.....	0	0	16	0	0	0	2	2	0	0	2	4	0	0	2	0	0	16	0	0	0	6	8	58
October.....	0	0	0	0	2	2	2	0	0	0	2	0	2	0	0	0	0	0	0	2	0	0	0	12
November.....	0	0	0	0	4	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	8
December.....	0	0	0	0	0	2	0	0	8	0	0	0	0	0	0	0	0	2	0	4	0	0	0	16
January.....	0	0	0	0	0(2)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	4	0	0	0	6(2)
February.....	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	8	18
March.....	0	0	0	0	8(2)	6	2	0	2	0	0	0	0	0	0	0	0	4	0	180(5)	4(1)	34	32	272(8)
April.....	0	0	0(4)	0	0	0	0	4	—	0	0	0	0	6	0	2	2	2	0	6	4	10	4	40(4)
May.....	0	0	0	0	0	2	2	0	—	0	0	0	0	0	16(2)	0	2	0(17)	0	0	0	0	0(2)	22(21)
June.....	0	0	0	0	0	0	0	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total.....	2	0	18(4)	14	14(4)	14	16	20	28	2	4	14	12	6	22(2)	8	6	28(17)	0	198(5)	22(1)	58	54(2)	560(35)

Reprint from "Commerce & Industry", February, 1959

TABLE VII.—*S. serratodentata.*

Station.	Depth. (Metres).	Spring (September. October. November.) Occurrence.	Mean Temp. C.	Summer (December. January. February.) Occurrence.	Mean Temp. C.	Autumn (March. April. May.) Occurrence.	Mean Temp. C.	Winter (June. July. August.) Occurrence.	Mean Temp. C.
R	140	6	13·00	0	11·43	8	11·26	0	13·04
H	290	2	14·68	2	13·47	8	13·89	2	14·29
G	380	4	14·97	0	14·36	4	15·22	8	14·57
T	370	2	15·16	0	16·92	4	15·26	14	14·97
Total Occurrence		14		2		24		24	
Average Temperature			14·45		14·04		13·91		14·22
Q	110	0	10·91	2	10·78	0	11·02	0	12·89
I	260	4	14·53	0	13·63	0	12·74	0	13·49
F	300	6	15·58	0	15·01	0	14·93	8	14·09
A	420	2	16·07	0	15·40	0	15·63	10	15·01
Total Occurrence		12		2		0		18	
Average Temperature			14·27		13·70		13·58		13·87
N	80	0	10·52	0	10·85	6	10·42	0	11·90
O	160	2	11·86	0	11·70	16	11·85	4	12·86
J	210	2	13·11	0	13·22	2	13·32	4	13·90
E	290	0	14·52	0	14·51	4	14·58	2	13·81
B	380	16	15·34	2	15·15	6	15·18	4	14·91
Total Occurrence		20		2		34		14	
Average Temperature			13·07		13·09		13·07		13·48
M	80	0	9·98	0	10·44	0	10·88	0	11·86
L	130	2	11·68	8	11·72	186	11·39	2	12·91
K	170	0	12·81	0	12·35	8	12·66	14	13·41
D	250	6	14·95	6	13·99	44	14·34	2	13·97
C	360	8	15·93	8	15·13	36	15·30	2	14·61
Total Occurrence		16		22		274		20	
Average Temperature			13·07		12·73		12·91		13·35
Total Occurrence		62		28		332		76	
Average Temperature			13·64		13·34		13·33		13·69

Reprint from "Commerce & Industry", February, 1959

Table VIII.

S. enflata N70V and N100H (numbers taken in N100H-net given in brackets).

	U.	V.	W.	X.	R.	H.	G.	T.	S.	Q.	I.	F.	A.	N.	O.	J.	E.	B.	M.	L.	K.	D.	C.	Total.
July.....	44	0	0	0	2	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0	0	2	54
August.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
September.....	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	6
October.....	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
November.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December.....	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
January.....	0	0	0(1)	0	0	0	0	2	0	0	0	0	0(1)	0	0	0	0	0	0	0	0	0	2(2)
February.....	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
March.....	0	0	0	0	0	0	0	0	0	0	0	0	0(1)	0	0	0	0	0(1)	0	0	0	0	0(2)
April.....	0	0	0(9)	0	0	0	0	2	—	0	0	0	0	0	0	0	0	0	0	0	0	0	2(9)
May.....	0	0	0	0	0	0	0	0	—	0	0	0	2(5)	0	0	0	0	0	0	0	0	0(1)	2(6)
June.....	0	0	0	0	0	0	0	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	44	0	2(10)	0	2	4	2	6	3	0	0	6	2(7)	0	0	0	0	0(1)	0	0	2	0	2(1)	75(19)

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TABLE IX.

Pterosagitta draco.

Date.	Station.	Depth. (metres).	Number of Specimens.	Temperature °C.	Salinity °/₀₀.
16/8/54	V	180	2	14·03	35·25
20/10/54	V	180	4	15·82	35·37
16/8/54	W	580	2	14·40	35·32
16/2/55	W	580	2	17·05	35·31
17/8/54	X	150	2	13·59	35·16
23/9/54	X	150	2	14·65	35·31
23/7/54	R	140	4	14·89	35·25
21/10/54	H	290	4	15·23	35·35
21/10/54	G	380	6	15·54	35·40
17/8/54	T	370	2	14·56	35·34
24/7/54	S	360	4	15·03	35·35
24/9/54	B	380	4	14·65	35·35
25/7/54	D	250	2	14·44	35·22
26/11/54	F	300	2	16·71	35·41
26/7/54	O	160	2	14·44	35·25
19/8/54	O	160	2	12·97	35·09
26/7/54	J	210	2	14·91	35·34
26/9/54	K	170	2	12·80	35·00
23/10/54	K	170	2	12·65	35·07

Total=52.

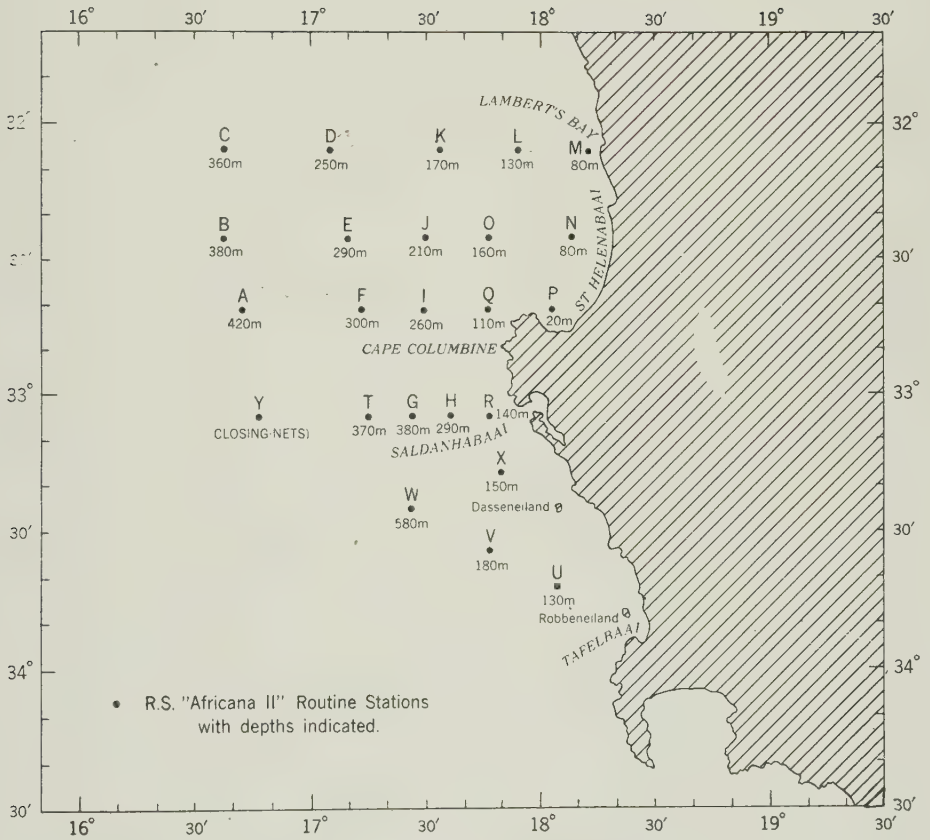

PLATE I. THE ROUTINE RESEARCH AREA

Trigsurvey, 1958

Government Printer, 1958

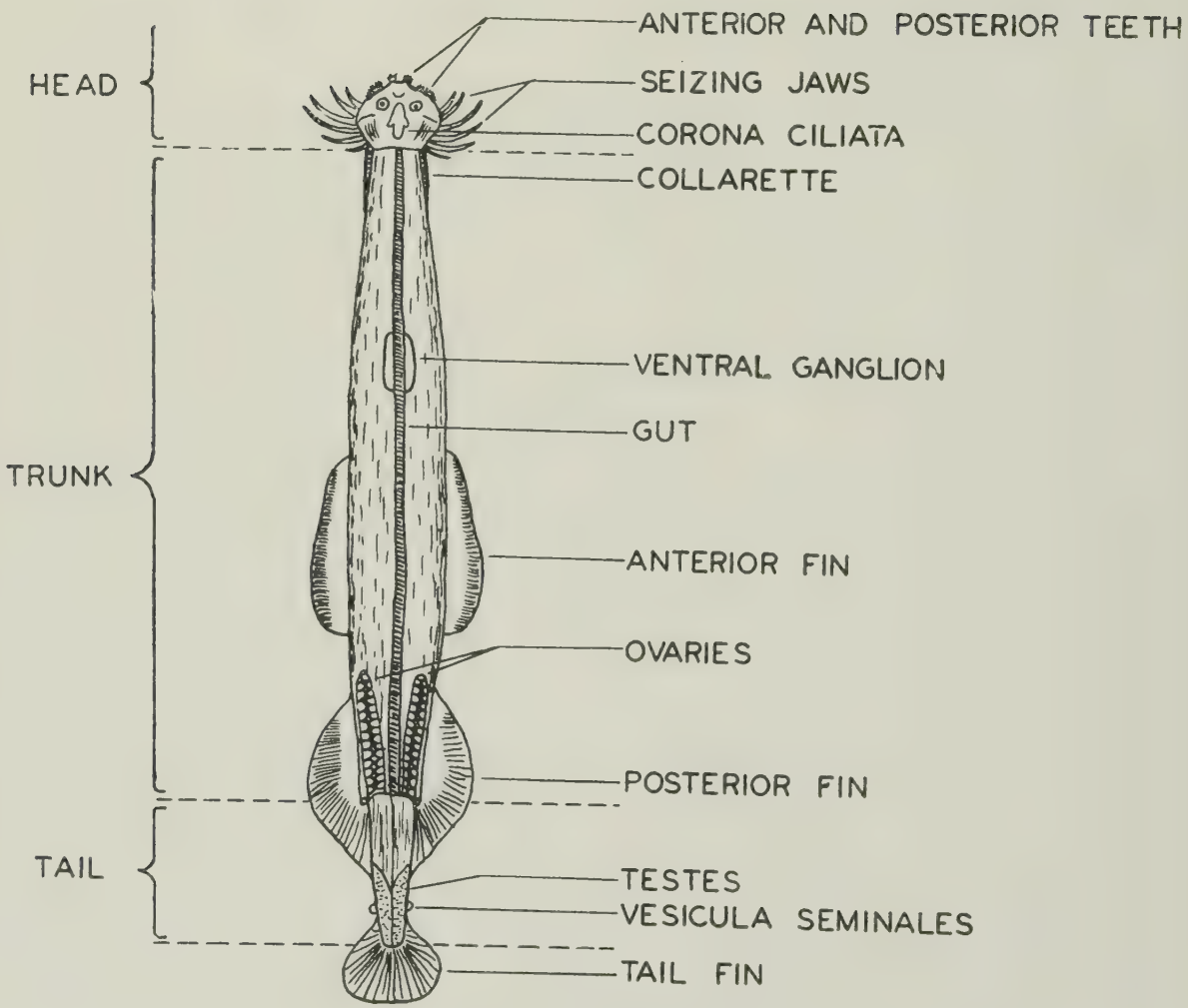

PLATE II. DIAGRAM OF A TYPICAL CHAETOGNATH.

Scatter Diagram I.

(Temperature/Salinity.)

Average Temperatures °C (0–50 metres)=X.

Average Salinities °/₀₀ (0–50 metres)=Y.

	10·0–10·4	10·5–10·9	11·0–11·4	11·5–11·9	12·0–12·4	12·5–12·9	13·0–13·4	13·5–13·9	14·0–14·4	14·5–14·9	15·0–15·4	15·5–15·9	1	2	3	4	5	6
													f	y_s	fy_s	fy_s^2	$\Sigma x_s y_s$	$y_s \Sigma x_s y_s$
35·25–35·29...												III	3	12	36	432	33	396
35·20–35·24...										I	II		3	11	33	363	29	319
35·15–35·19...										I			1	10	10	100	9	90
35·10–35·14...									II				2	9	18	162	16	144
35·05–35·09...							I	II	I				4	8	32	256	28	224
35·00–35·04...													0	7	0	0	0	0
34·95–34·99...					I	I							2	6	12	72	9	54
34·90–34·94...					I	I							2	5	10	50	9	45
34·85–34·89...					I								1	4	4	16	4	16
34·80–34·84...			I	I									2	3	6	18	5	15
34·75–34·79...		I											1	2	2	4	1	2
34·70–34·74...		I											1	1	1	1	1	1
34·65–34·69...													0	0	0	0	0	0
1 f	0	2	1	1	3	2	1	2	3	2	2	3	22		164	1,474	144	1,306
2 x_s	0	1	2	3	4	5	6	7	8	9	10	11			Σfy_s	Σfy_s^2		$\Sigma x_s y_s$
3 fx_s	0	2	2	3	12	10	6	14	24	18	20	33	144	Σfx_s				
4 fx_s^2	0	2	4	9	48	50	36	98	192	162	200	363	1,164	Σfx_s^2				
5 $\Sigma y_s x_s$	0	3	3	3	15	11	8	16	26	21	22	36	164					
6 $x_s \Sigma y_s x_s$	0	3	6	9	60	55	48	112	208	189	220	396	1,306	$\Sigma x_s y_s$				

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Calculation I.

(Figures derived from scatter diagram I).
Temperature/Salinity correlation.

$$\Sigma xy = \left[\Sigma x_{\backslash} y_{\backslash} - \frac{(\Sigma f x_{\backslash})(\Sigma f y_{\backslash})}{N} \right] ixiy.$$

$$= \left[1306 - \frac{(144)\ (164)}{22} \right] (0 \cdot 5)\ (0 \cdot 5)$$

$$= 5 \cdot 81$$

$$\Sigma x^2 = \left[\Sigma f x_{\backslash}^{\ 2} - \frac{(\Sigma f x_{\backslash})^2}{N} \right] ix^2$$

$$= \left[1164 - \frac{(144)^2}{22} \right] (0 \cdot 5)^2$$

$$= 55 \cdot 36$$

$$\Sigma y^2 = \left[\Sigma f y_{\backslash}^{\ 2} - \frac{(\Sigma f y_{\backslash})^2}{N} \right] iy^2$$

$$= \left[1474 - \frac{(164)^2}{22} \right] (0 \cdot 05)^2$$

$$= 0 \cdot 63$$

$$rxy = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \quad \Sigma y^2}}$$

$$= \frac{5 \cdot 81}{\sqrt{(55 \cdot 36)\ (0 \cdot 63)}}$$

$$= \cdot 984$$

Calculation II.

S. friderici: Calculation of r for the 10·0–14·0°C temperature range.

Station.	X	Y	X^2	Y^2	XY
U	12·17	328	148·11	107584	3991·76
V	13·33	76	177·69	5776	1013·08
X	12·55	420	157·50	176400	5271·00
R	12·18	816	148·35	665856	9938·88
Q	11·40	1416	129·96	2005056	16142·40
I	13·60	52	184·96	2704	707·20
N	10·92	672	119·25	451584	7338·24
O	12·07	638	145·68	407044	7700·66
J	13·39	54	179·29	2916	723·06
M	10·79	2030	116·42	4120900	21903·70
L	11·92	1210	142·09	1464100	14423·20
K	12·81	556	164·10	309136	7122·36
Σ	147·13	8268	1813·40	9719056	96275·54

$$r = \frac{\Sigma XY - \frac{(\Sigma X)\ (\Sigma Y)}{N}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right]}}$$

$$= \frac{96275 \cdot 54 - \frac{(147 \cdot 13)\ (8268 \cdot 00)}{12}}{\sqrt{\left[1813 \cdot 40 - \frac{(147 \cdot 13)^2}{12}\right]\left[9719056 \cdot 00 - \frac{(8268 \cdot 00)^2}{12}\right]}}$$

$$= \frac{-5097 \cdot 03}{\sqrt{38051941 \cdot 84}}$$

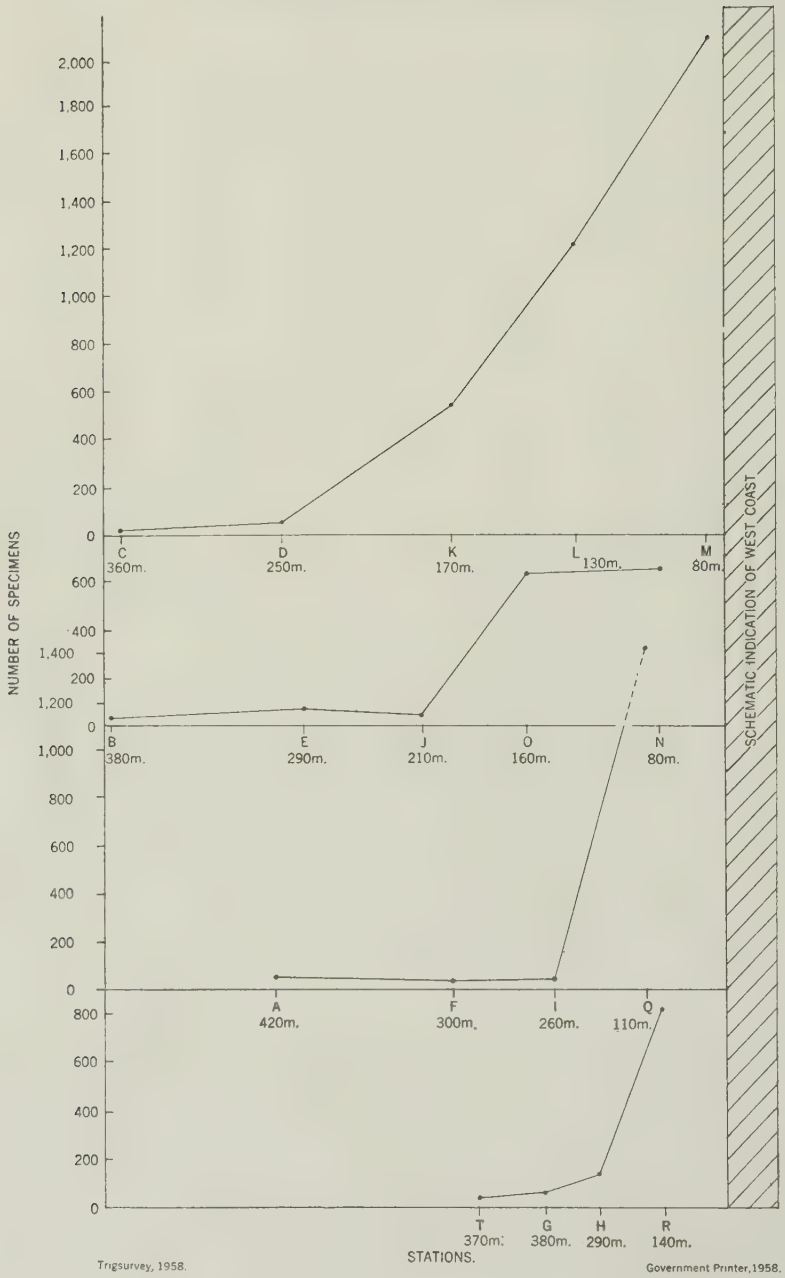
$$= \frac{-5097 \cdot 03}{6168 \cdot 63}$$

$$= -0 \cdot 826$$

Note.—X = Average temperatures.
Y = Numbers of *S. friderici*.

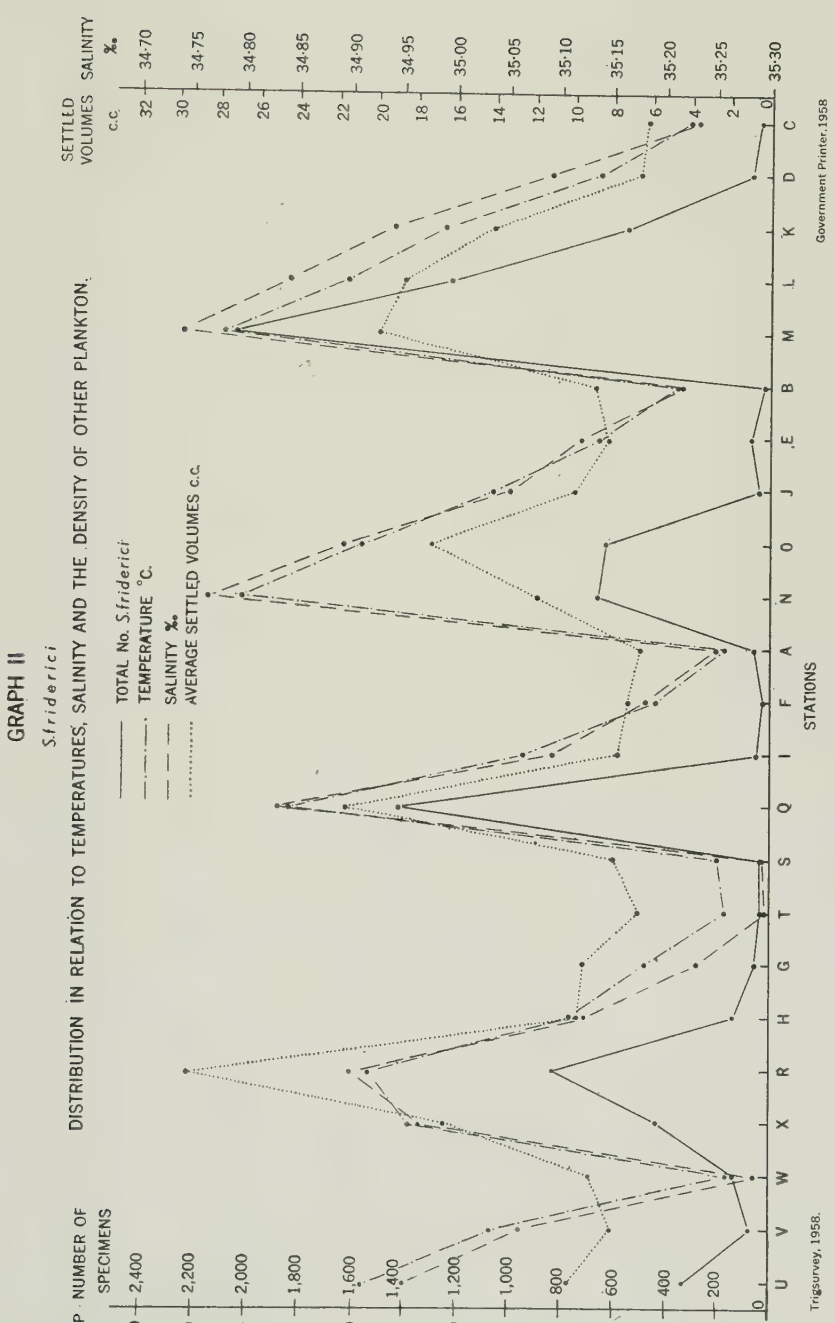
GRAPH I

OCCURRENCE OF *S.friderici* ON AN ANNUAL BASIS.



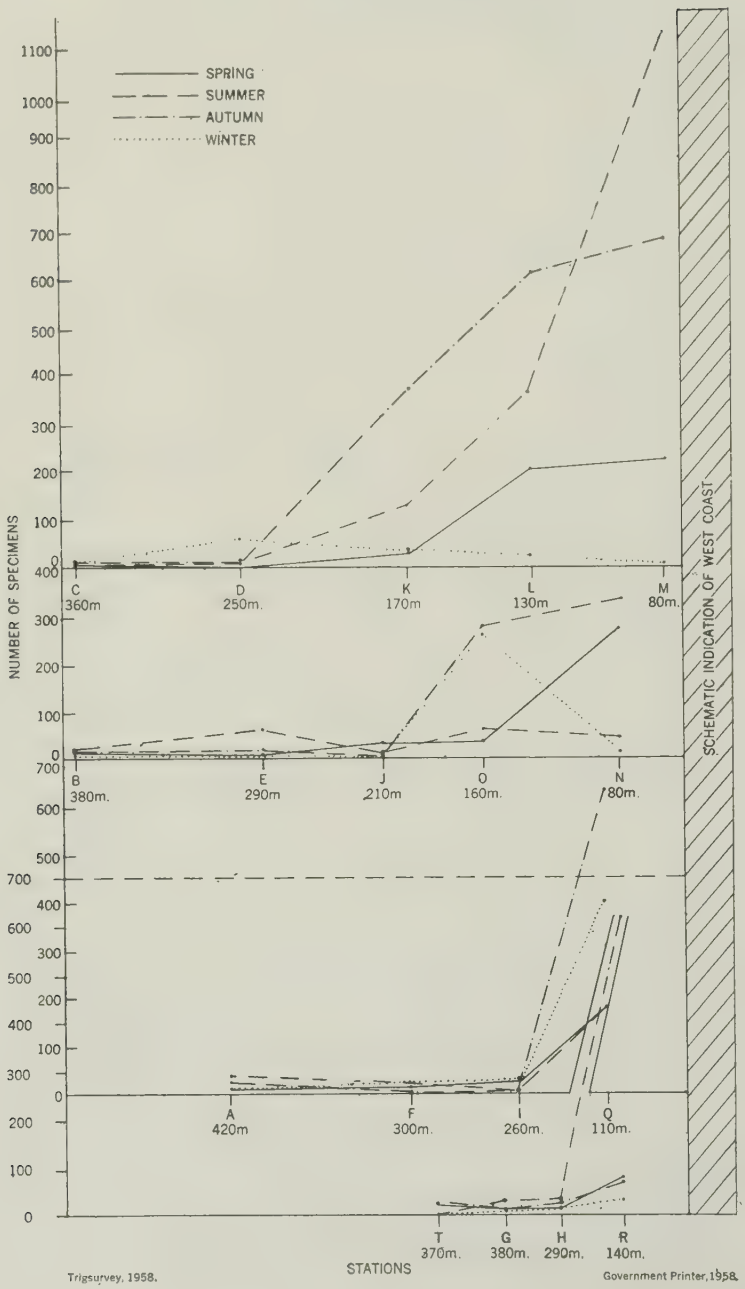
Trigsurvey, 1958.

Government Printer, 1958.


GRAPH II
S. frideríci
DISTRIBUTION IN RELATION TO TEMPERATURES, SALINITY AND THE DENSITY OF OTHER PLANKTON.
TOTAL No. S. frideríci
TEMPERATURE °C.
SALINITY ‰
AVERAGE SETTLED VOLUMES c.c.
TEMP °C
NUMBER OF SPECIMENS
SETTLED VOLUMES c.c.
SALINITY ‰
STATIONS
Trigsurvey, 1958.
Government Printer, 1958

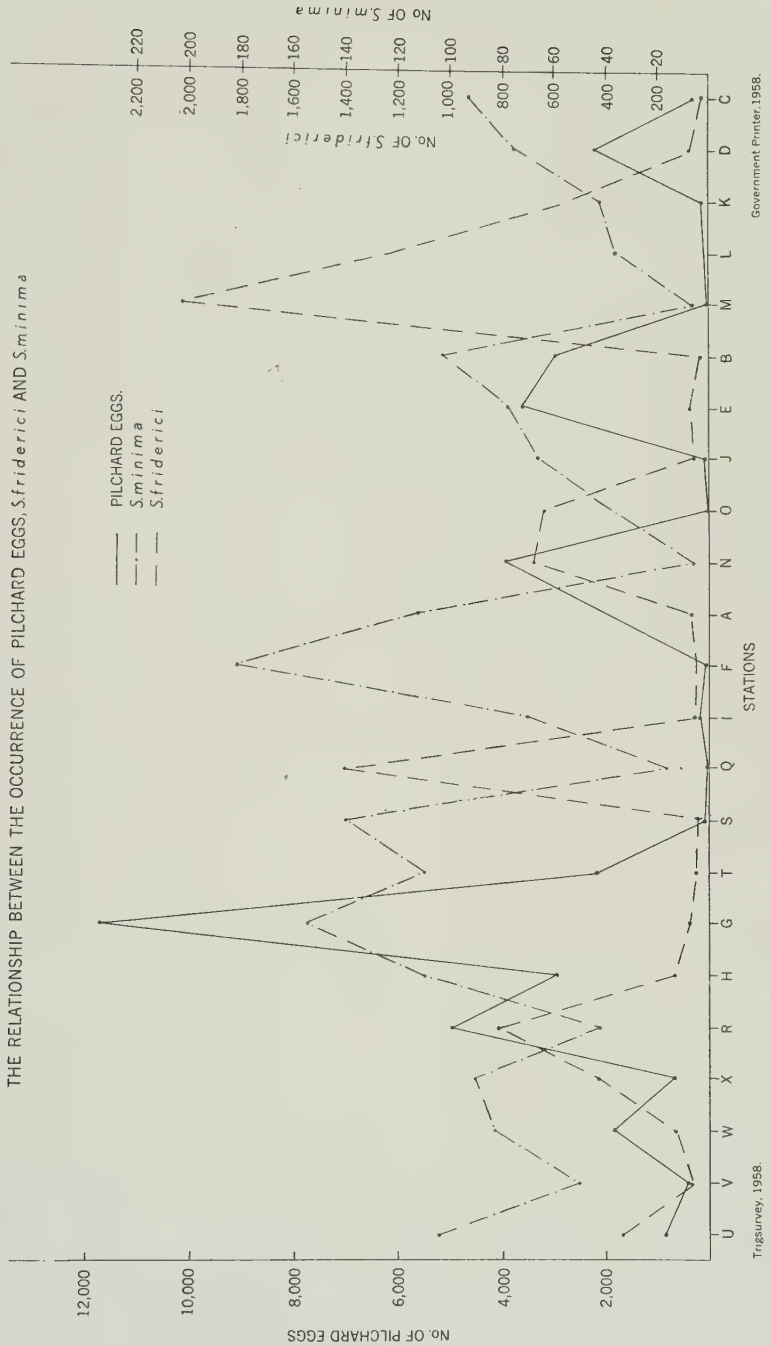
GRAPH III

S.friderici — OCCURRENCE ON A SEASONAL BASIS.



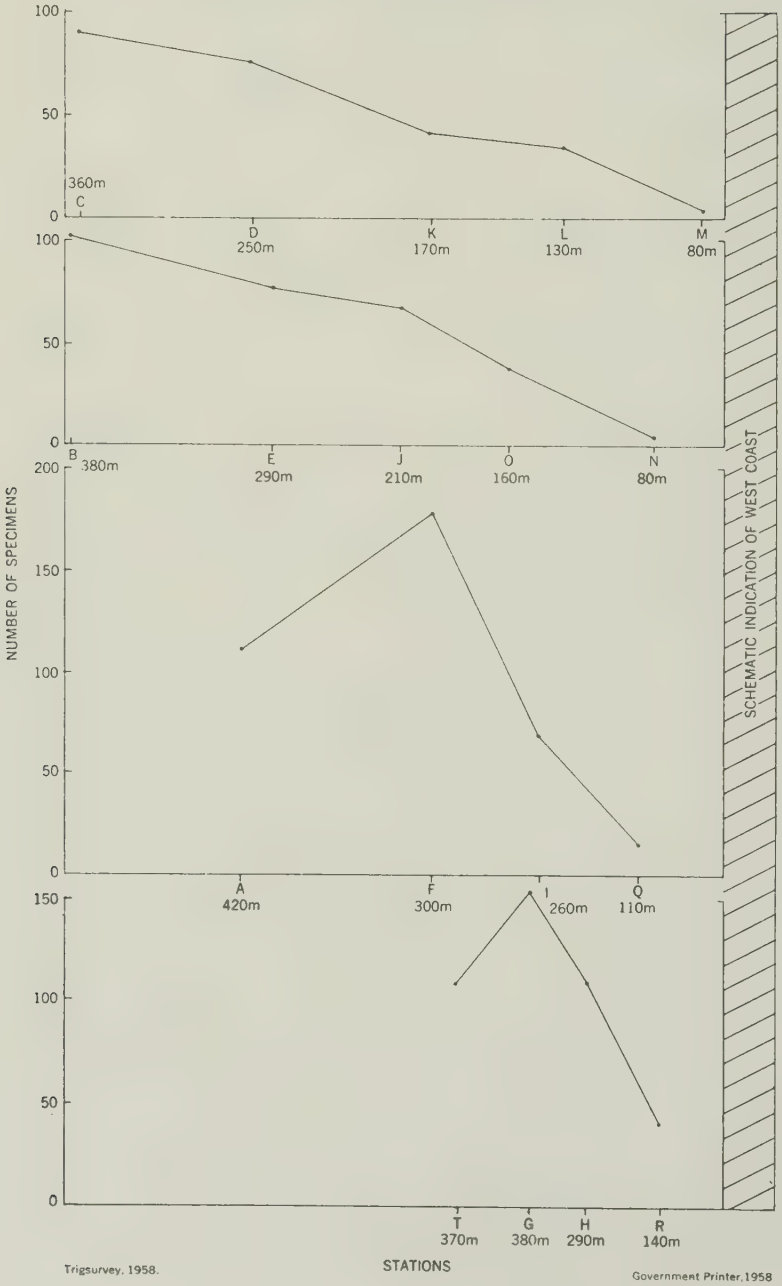
GRAPH IV

THE RELATIONSHIP BETWEEN THE OCCURRENCE OF PILCHARD EGGS, *S.frideric*i AND *S.minima*



GRAPH. V

OCCURRENCE OF *S. minima* ON AN ANNUAL BASIS.



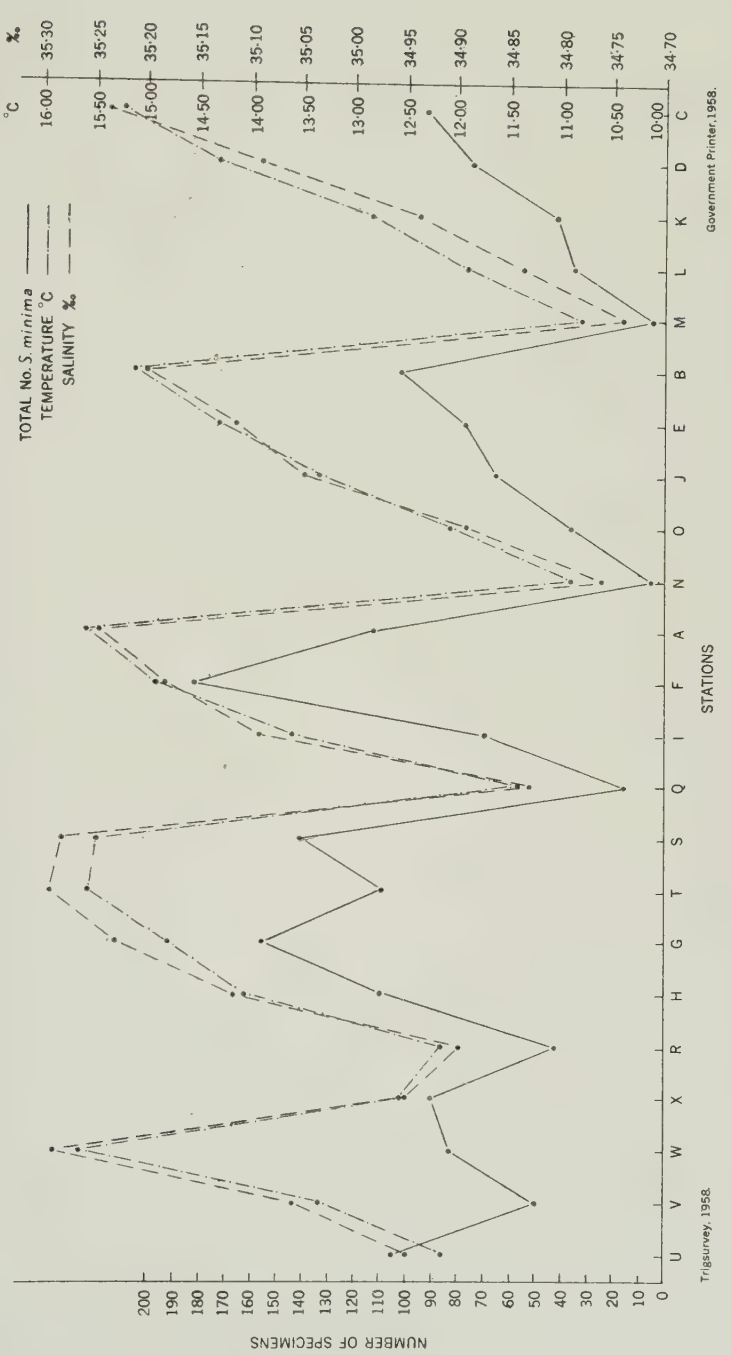
Trigsurvey, 1958.

Government Printer, 1958

GRAPH VI

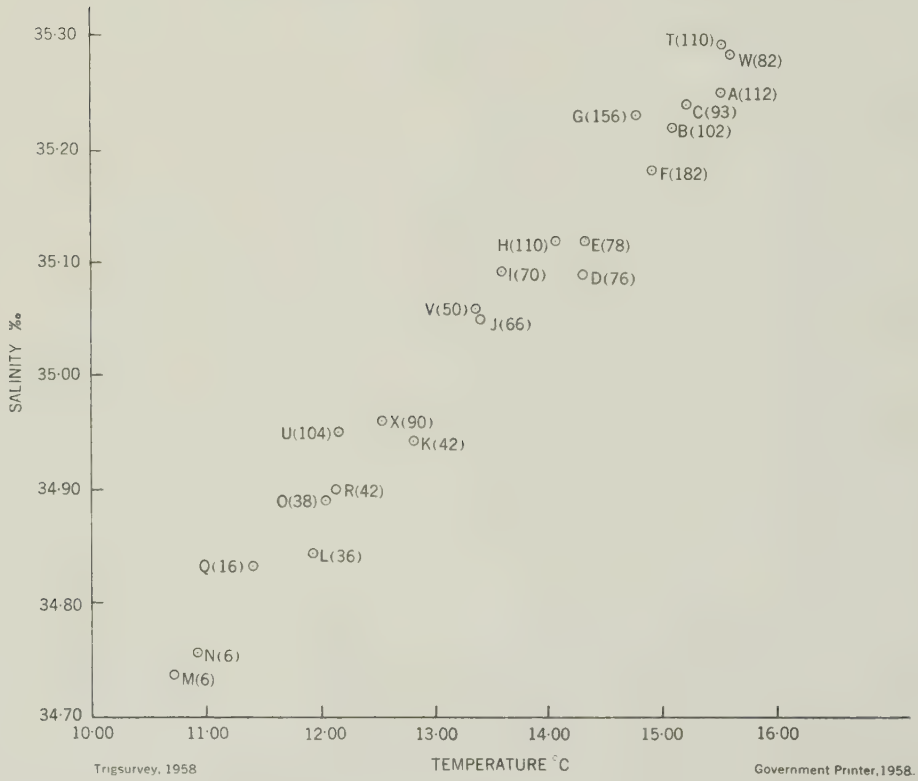
S. minima

DISTRIBUTION IN RELATION TO TEMPERATURES AND SALINITIES.



GRAPH VII

THE RELATIONSHIP BETWEEN THE OCCURRENCE OF *S. minima*
AND THE TEMPERATURE AND SALINITY OF THE WATER OF THE 0—50m. LAYER



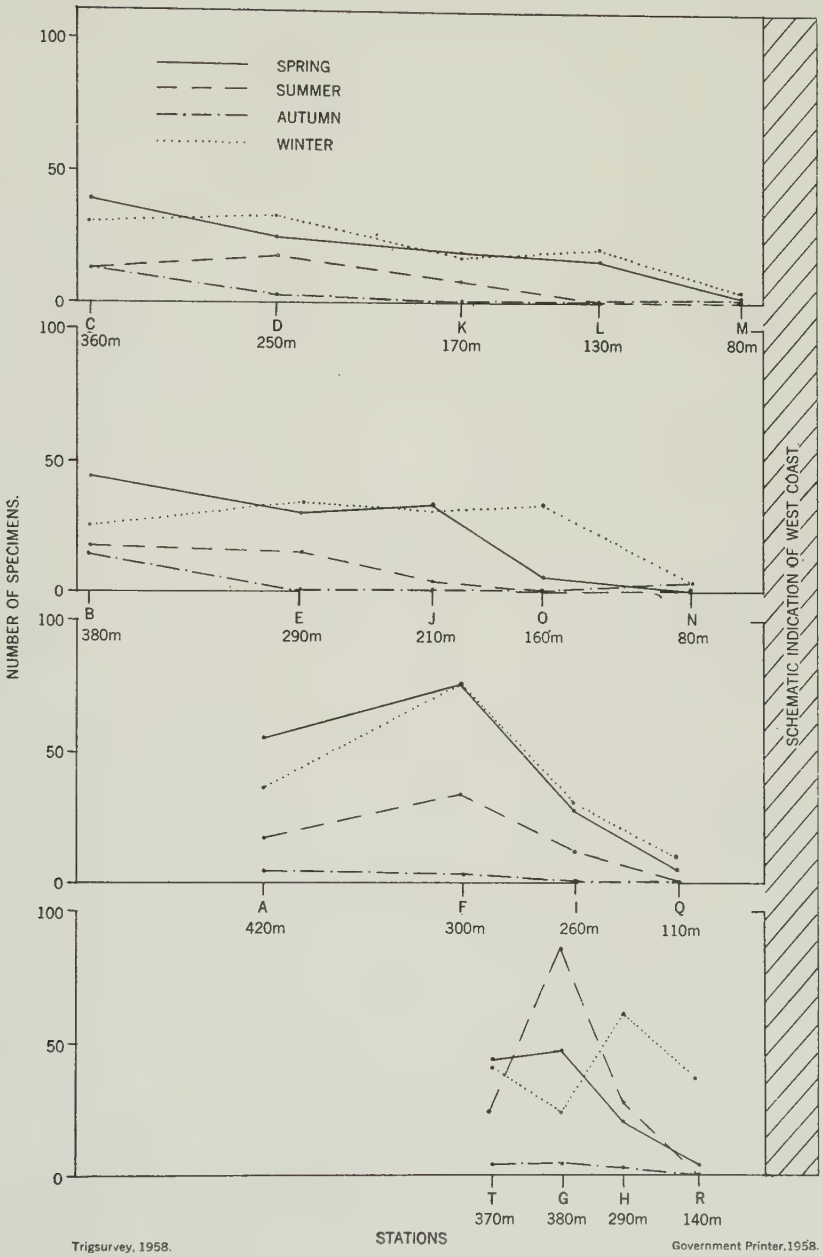
Trigsurvey, 1958

Government Printer, 1958.

GRAPH VIII

S. minima

OCCURRENCE ON A SEASONAL BASIS.

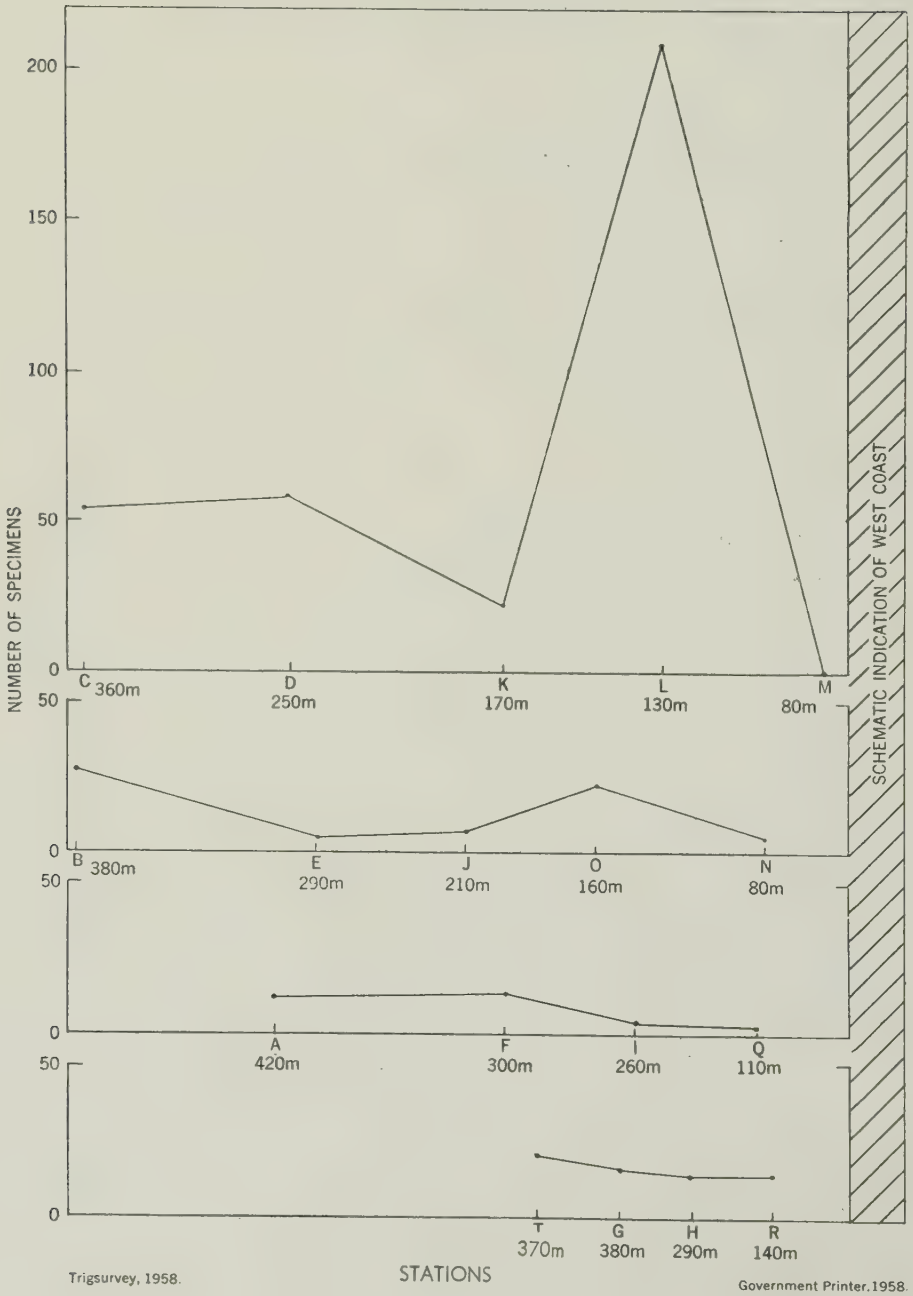


Trigsurvey, 1958.

Government Printer, 1958.

GRAPH IX

OCCURRENCE OF *S.serratodentata* ON AN ANNUAL BASIS.



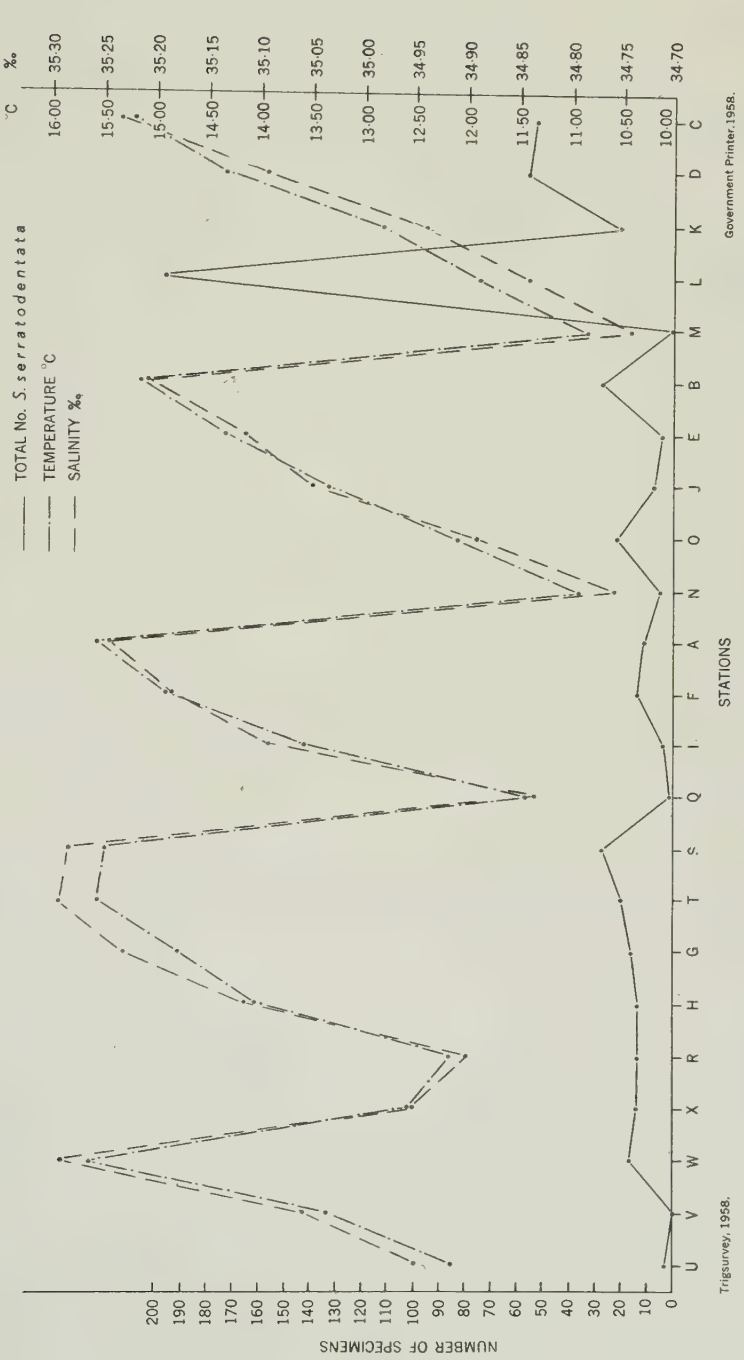
Trigsurvey, 1958.

Government Printer, 1958.

GRAPH X

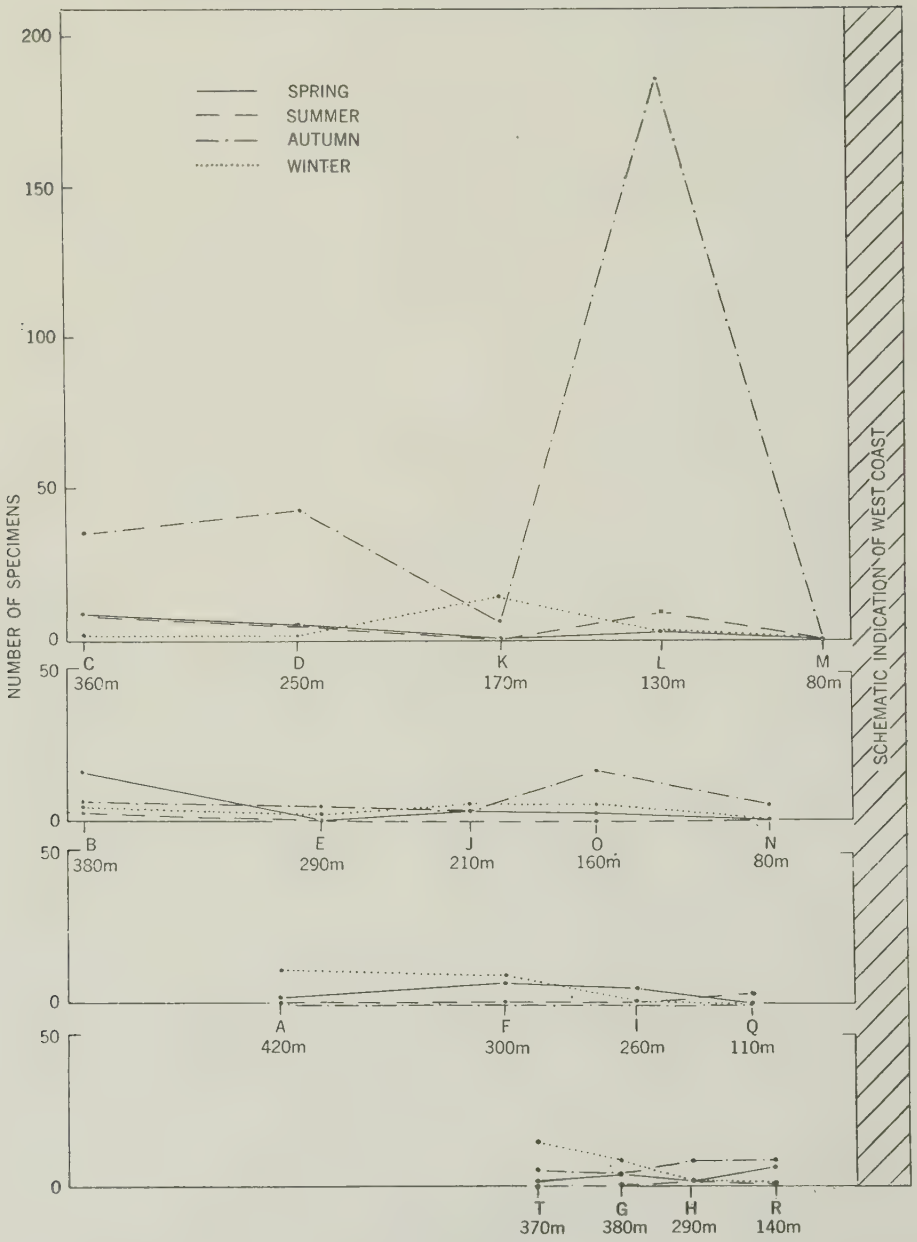
S. serratodentata

DISTRIBUTION IN RELATION TO TEMPERATURES AND SALINITIES.



GRAPH XI

S. serratodentata — OCCURRENCE ON A SEASONAL BASIS.

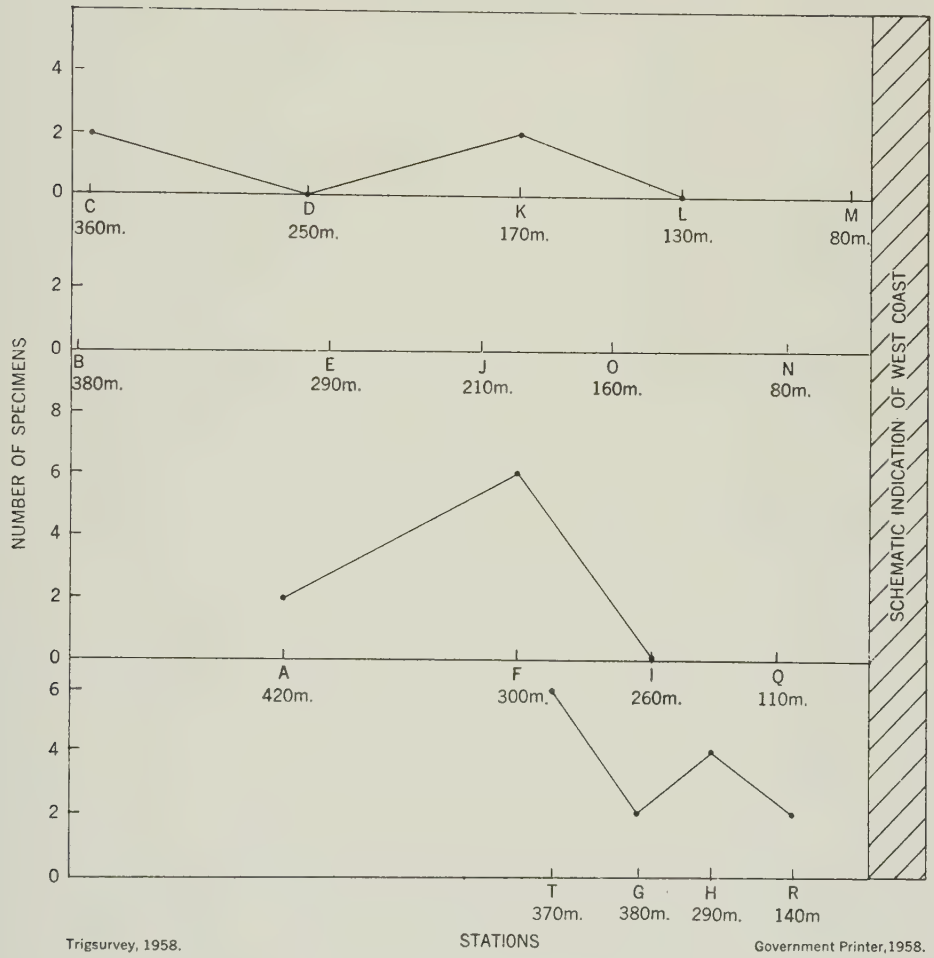


Trigsurvey, 1958.

Government Printer, 1958

GRAPH XII

OCCURRENCE OF *S enflata* ON AN ANNUAL BASIS.

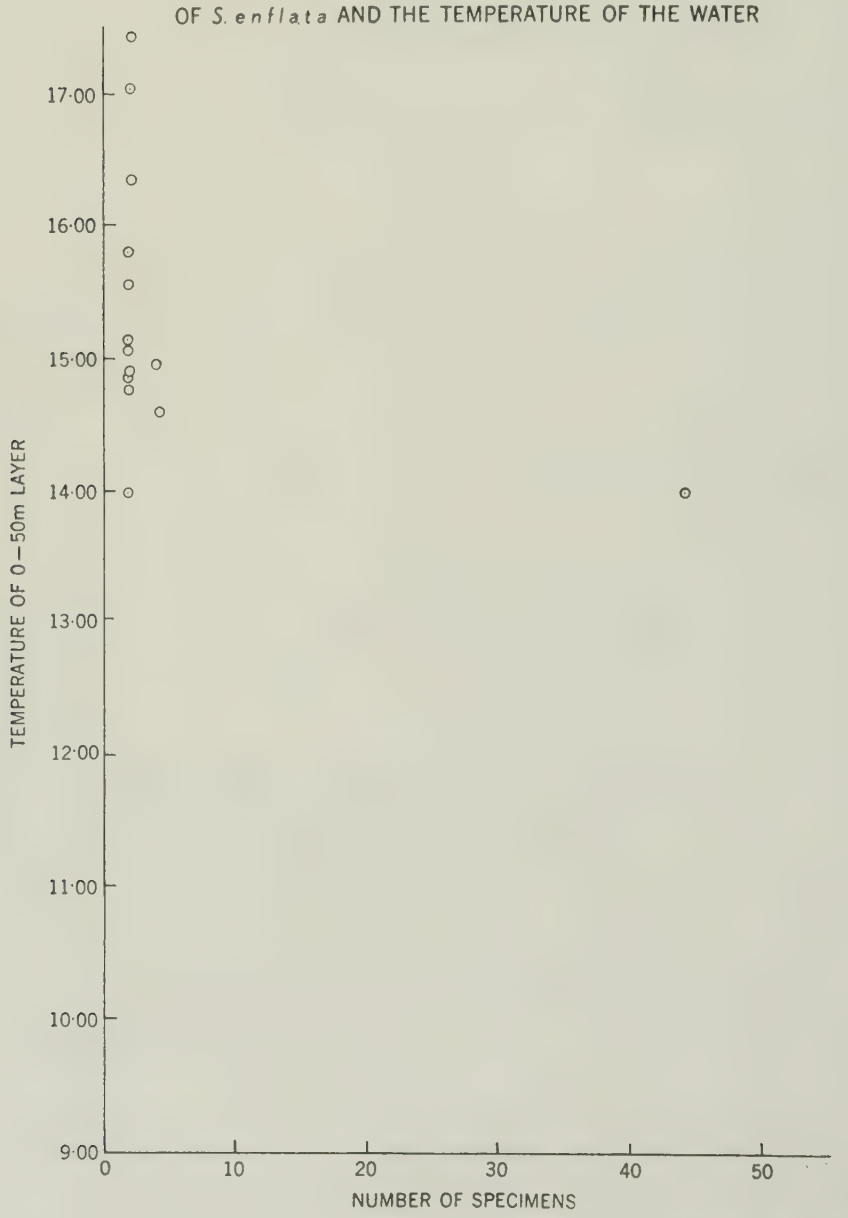


Trigsurvey, 1958.

Government Printer, 1958.

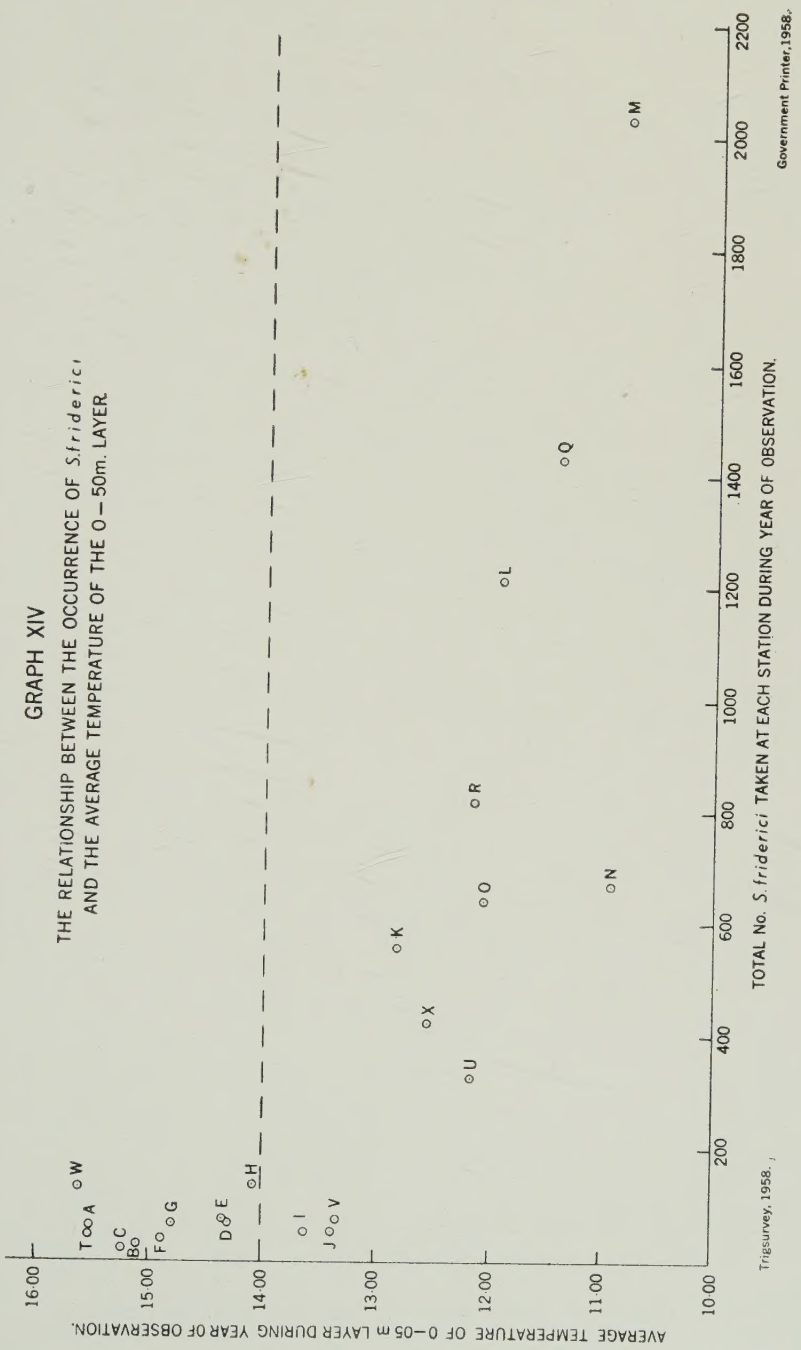
GRAPH XIII

THE RELATIONSHIP BETWEEN THE OCCURRENCE
OF *S. enflata* AND THE TEMPERATURE OF THE WATER



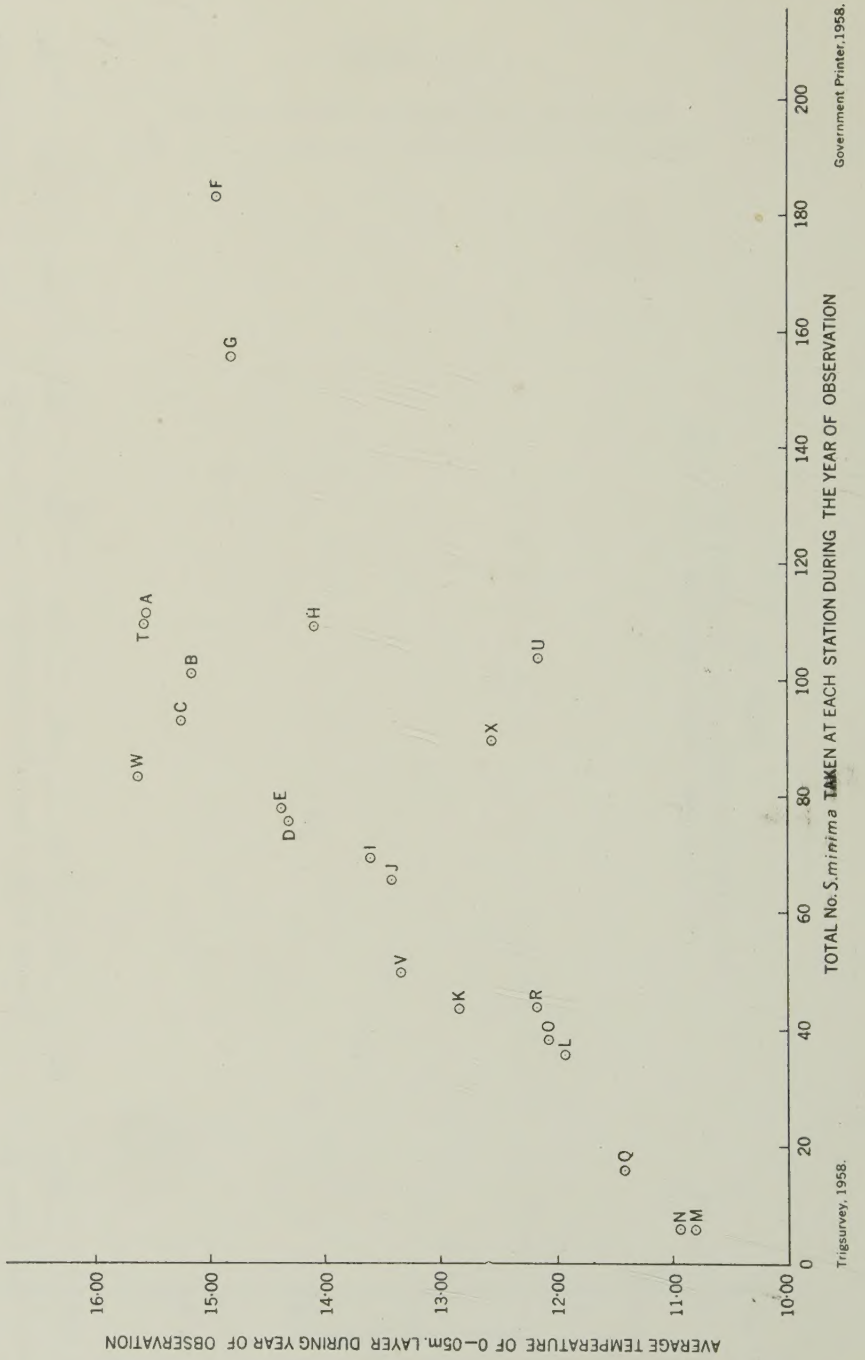
Trigsurvey, 1958.

Government Printer, 1958.


GRAPH XIV
THE RELATIONSHIP BETWEEN THE OCCURRENCE OF S.frideric
AND THE AVERAGE TEMPERATURE OF THE 0—50m. LAYER
AVERAGE TEMPERATURE OF 0—05 m LAYER DURING YEAR OF OBSERVATION.
16·00
15·00
14·00
13·00
12·00
11·00
10·00
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
TOTAL No. S. frideric TAKEN AT EACH STATION DURING YEAR OF OBSERVATION.
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
Q
R
U
V
W
X
Trigsurvey, 1958.
Government Printer, 1958.

GRAPH XV

THE RELATIONSHIP BETWEEN THE OCCURRENCE OF *S.minima* AND THE AVERAGE TEMPERATURE OF THE 0—50m. LAYER



Trigsurvey, 1958.

Government Printer, 1958.